

Visualization Techniques for Climbing Self-Assessment

Master Thesis

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St. Poelten, June 17, 2015

Declaration of Honour

I affirm, that

- I have drafted this thesis independently, have not used other than stated sources and means, and have not used any other illegitimate assistance.
- I have, neither domestically nor abroad, submitted this thesis to an examiner for inquiry or in any other form as a test paper.

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Signaturenen

Kurzfassung

Im Zuge dieser Diplomarbeit wurde eine Designstudie mit dem Ziel erstellt, ein System für Kletterer zu entwickeln, das Trainingsdaten darstellt und Einschätzungen des Trainingsstatus durchführt. Wearable Devices, die von ClimbAX entwickelt wurden, stellen die Basis für die gesamte Arbeit dar. Die aufgenommenen Daten dieser Sensoren wurden als Grundlage für die Visualisierungen verwendet. Im Zuge der Arbeit wurde ein technischer Prototyp, bestehend aus einer mobilen Webanwendung und einem Präsentations- und Analysetool für Desktopgeräte, entwickelt.

Mehrere Applikationen für die Aufzeichnung von Sport wie Laufen, Radfahren oder Krafttraining sind am Markt erhältlich. Im Bereich des Klettersports, ob in der Kletterhalle oder direkt am Felsen, konnten keine Anwendungen identifiziert werden. Daher war das Ziel dieser Arbeit, für die Klettersportlerinnen und die Klettersportler eine Applikation zu generieren, die die komplexen Anforderungen der Sportlerinnen und Sportler erfüllt.

Es wurde ein semi-strukturiertes Interview mit Kletterinnen und Kletterern durchgeführt, um die Anforderungen an solch ein System herauszufinden. Zur Evaluierung von Problemen im Interface, des entwickelten Konzeptes, fand ein Experten-Interview statt. Das implementierte System wurde im Zuge einer Usability-Studie auf seine Benutzerinnenfreundlichkeit getestet. Die Ergebnisse des Interviews mit der Zielgruppe zeigten, dass das zu entwickelnde System Möglichkeiten für eine manuelle Eingabe von Daten zu einer Kletterroute bereitstellen sollte. Die mobile Webanwendung bietet der Kletterin und dem Kletterer die Möglichkeit einer manuellen Eingabe als auch eine Analyse der aufgezeichneten Daten der beiden Sensoren. Das Präsentations- und Analysetool gibt detaillierte Einblicke in die Trainingsdaten und lässt mehr Raum für Analysen offen. In beiden Konzepten wurden Visualisierungsarten verwendet, die in der Zielgruppe bekannt und leicht zu interpretieren waren. Besonders die einfache Benutzbarkeit des Systems wurde von der Zielgruppe stark hervorgehoben.

In dieser Arbeit wird ein weitreichender Einblick in die Anforderungen einer Applikation für diese spezielle Zielgruppe als auch in die Verwendungsweisen und Interaktionen zwischen User und Applikation ermöglicht. Außerdem wird ein Proof-of-Concept eines Systems für Kletterer mit D3.js implementiert.

Abstract

In this design study, the aim was to develop a system for climbers which gives insights to training data and provides assessments of climbing training. Data of wrist-worn sensors developed by ClimbAX formed the basis. A concept and prototype implemented in D3.js, based on a mobile web application and a desktop tool for presentation and analysis, were created. Various quantified-self applications for tracking daily activities such as running, cycling or strength training are available on the market. By analyzing different devices, a lack of self-assessment tools for climbers especially for indoor and outdoor tours is identified.

A contextual semi-structured interview, an expert review, as well as a usability study were conducted to identify the requirements of climbers. To evaluate and improve the developed concept an expert review and a usability study were performed. The results of these interviews showed the importance of providing manual input possibilities besides the automatically detected data of the wrist-worn device. Therefore, the mobile web application, developed in the course of this thesis, provides possibilities to add data manually. Visualization techniques, integrated into the applications, give users an overview of their training data. The web application is a tool to analyse data in more detail and allows the user to react to changes in the climbing training. The implementation provides visualizations, such as bar charts, line plots or donut charts, which were identified as well known. According to the findings of the interview, the system should be easy to use and avoid visualizations showing data of a long training periode.

These findings have significant implications for the understanding of how climbers will interact with quantified self-applications and what are the individual requirements for such a system are.

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1 Introduction

Sensing technologies supporting health and fitness are a growing area of interest. People now have access to many sources of data about their health and wellbeing. Commercial systems have been developed, and research has been done to track and monitor personal information such as weight, steps, sleep behaviour and physical activities. These technologies allow easy data collection by using wearable devices or low-cost mobile apps. A wide variety of research fields, spanning mobile and ubiquitous computing research, lifelogging, medicine, and behavioural economics focus on the development, use and evaluation of wearable personal activity sensing technology. Positive effects of the usage of such sensors are documented in numerous studies. Successful weight loss (Brown, Chetty, Grimes, & Harmon, 2006; Eastwood, Travis, Morgenstern, & Donaho, 2007; Mattila et al., 2008) and getting fitter by monitoring physical activity (King et al., 2008; Consolvo, 2012) are some examples of study results.

The representation of data tracked by wearable devices via native applications and web applications is important to the iterative process of self-reflection. Available commercial devices represent detected data in the form of charts such as Spiral Timeline and Bubble view (Li, Dey, & Forlizzi, 2010; Cuttone, Lehmann, & Larsen, 2013) or line plots. Dashboard design approaches (De Croon, De Buyser, Klerkx, & Duval, 2014), avatars (Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006), notifications (Bentley & Tollmar, 2013), narrative (Pavel, Trossen, Holweg, & Callaghan, 2013) and abstract art (Fan, Forlizzi, & Dey, 2012) are also integrated into the quantified-self applications.

Different wearable devices for various sports like running, cycling or fitness training, are available on the market, which provide mechanisms to enable users to record and track metrics automatically related to the sport and health activity. These systems help the user gain fitness by providing an assessment tool in the form of auditory feedback or various other approaches by giving rewards for physical activities. However, to date there are no devices or services available for supporting climbing sports. Only the commercial sports application Endomondo ("Endomondo – Laufen & Radfahren," 2015) provides exercise type "climbing".

Special parameters for climbing such as power and stability of the movement are not part of the detection functionalities of the Endomondo application. Chapter 3 gives a deeper insight into the currently available techniques and systems in the field of quantified-self.

1.1 Background

The sport of climbing sport has become increasingly popular and is now widely enjoyed these days. As a recreational activity climbing holistically improves both physical and mental fitness. Similar to other sports, professional climbing requires physical conditioning, training and background knowledge of sports science related to motion sequences. At the amateur level, coaching is a service offered by indoor climbing centres and it is often a group experience with a typical 1:8 coach to student ratio.

Climbing requires a range of physical abilities (Ladha, Hammerla, Olivier, & Plötz, 2013). For example climbing long mountain routes requires very good general stamina and tolerance to high altitudes. To succeed in bouldering¹ physical strength, good general coordination, and muscular flexibility are important. To perform well in climbing the following skill set is needed. Power is used for the transitions between holds (Quaine, Martin, & Blanchi, 1997), control over limb movement (Testa, Martin, & Debû, 1999) is needed and stability whilst on a hold (Horst, 2008), (White & Olsen, 2010). It has been demonstrated that parameters relating to these physical skills can be measured at the interface of the hand and the hold (Ladha et al., 2013; Pansiot, King, McIlwraith, Lo, & Yang, 2008; Schmid, Shea, Friedman, & Srivastava, 2007).

¹ Bouldering is the discipline of ropeless climbing on small cliffs. It involves the ascent of relatively low-level routes on free standing boulders with just a crash pad to protect the climber in the case of a fall ("All About Bouldering," 2015; Fyffe & Peter, 1997).

1.2 Motivation

Measuring the performance of climbing movements is a complex matter. The physical condition, the motivation and also the factor of weather such as temperature or humidity can affect the performance of a climber (Fichtinger, Mrak, Hochholzer, & Gabl, 2008). Furthermore, the individual anatomy of athletes can be a crucial factor for performing well in climbing. In a basic training, climbing athletes acquire basic skills. Most of the climbers are willing to improve their climbing techniques, after visiting a basic climbing training. So they have to visit further courses, which are often expensive and time-consuming. If a self-assessment system would be available for climbers that support athletes via a digital coach, they could improve their climbing skills without further courses.

This way, the motivation behind this thesis is to process the given performance data of sensing devices to climbers with no technical expertise as data analyst. The application developed in this thesis should be able to give climbers feedback on their climbing training and provide a platform for analysing and exploring training data. Up to now, far too little attention has been paid to this topic. To date, there has been one study that has investigated the domain of climbing in the field of quantified-self applications. The startup ClimbAX utilises wrist-worn accelerometers to capture a climber's movement in naturalistic settings. "Climbing episodes and individual transitions are detected automatically, forming the basis for performance analysis." (Ladha et al., 2013) The system developed by ClimbAX replicates professional climbing assessment, like human coaches conduct it. The team of ClimbAX also created first designs to illustrate the collected data of climbers, which can be seen in Figure 1. The focus of the visualization is to visualize the trend of climbing sessions over time in combination with information about "average climbs per session" or "average duration per session". Key criteria – control, power, stability and time – that characterise a set of core skills every climber needs to possess and develop are defined by a move specific analysis of climbing (Ladha et al., 2013).



Figure 1: ClimbAX Online Tool Visualization Examples: Several visualization techniques provide insights into tracked data of the wearable sensors of one climbing day. (“Climbax - Demo Visualization,” 2015)

1.3 Methodology & Structure

Based on the existing data set and the work done by ClimbAX (Ladha et al., 2013) a design study (Sedlmair, Meyer, & Munzner, 2012) was conducted to develop a web-based mobile application and an interactive visual presentation and analysis tool for climbing. An iterative user-centered and problem-driven design approach was followed. In order to identify requirements for the development of a smartphone and desktop application, contextual interviews have been conducted. Based on the results, the system was designed and implemented. The data from the wrist-worn device of ClimbAX acted as basis for the thesis.

The interactive visualization platform, developed in the course of this thesis, represents new combinations of visualization for the sport of climbing. By designing a mobile application, ideas in terms of a logbook for climbing and a combination with the visualization tool for the desktop usage could be envisaged.

The user-centered design approach focused on hobby climbers who are motivated to enhance their climbing skills and trust in new technologies related to wearable devices and the power of visualizations. It is beyond the scope of this thesis to fully implement the concept. Only parts of the concept were implemented in D3.js as a proof-of-concept (Bostock, M., Ogievetsky, V., & Heer, J., 2011). The main technologies used to implement a scenario-based prototype (Beaudouin-Lafon & Mackay, 2003) were web technologies such as HTML, CSS and JavaScript.

The study offers some important insights into the requirements and needs of climbers as well as visualization techniques to display sensor data, tracked by the wrist-worn sensor of climbing movements.

In particular, this thesis will examine four main research questions:

- What are the possibilities to visually represents time-oriented, multivariate sensor data, collected by climbers to show pattern and behaviour in their training?
- What are the requirements of climbers?
- Which interactions can be integrated into the interface concept to improve easy exploration and analysis?
- Are the interactive visual presentation and analysis tool as well as the mobile web application easy to understand for none-experts and effective?

This thesis pursued the method of a design study based on *the nested model* for visualization design by Munzner (2009). The methodological approach taken in this study was a mixed methodology based on this four-level based validation method by Munzner. At the first level - characterise the task and data in the vocabulary of the problem domain – *contextual interviews* were conducted to understand the requirements of the specific domain. Further, a *literature survey* to find tools and applications in this research area was conducted. The results of the contextual interview and the literature survey were transformed to the second level of the nested model - abstract into operations and data types and design visual encoding and interaction techniques (Munzner, 2009).

The data collected by ClimbAX sensors formed the theoretical basis for the developed concept in this thesis. The results of the contextual semi-structured interviews were transformed into requirements and were integrated into the concept. The concept represents a solution for climbers to explore, analyse and find patterns in their training data in the form of high-fidelity wireframes. At the visual encoding and interaction design level, expert reviews were performed to

evaluate the resulting concept. Parts of the concept were implemented in the form of a prototype applying the JavaScript library D3.js. To meet the downstream approach of Munzner and validate against threats this prototype was examined by users of the target group in the form of a *usability study*.

The overall structure of the thesis can be divided into five chapters, including problem analysis, state of the art, concept, prototype implementation and prototype evaluation. The first section examines the given problem in this domain. The main issues addressed in this chapter are a) the results of the semi-structured contextual interviews and b) the data structure of the sensor device. Chapter 3 begins by displaying the theoretical dimensions of the research and shows what applications and systems are available for sport climbing and if a lack can be identified. This is followed by the concept description in chapter 4. This part presents the description of the developed system as well as the findings of the expert reviews conducted in the design process. A concept revision based on the results of the expert reviews is also part of this chapter. Chapter 5 contains the prototype implementation description of the mobile web application and the analysis and presentation tool. Section 6 presents the findings of the prototype evaluation, focusing on finding problems in the interface and getting feedback on the developed concept.

2 Problem Analysis

In order to identify requirements for a system for climbers contextual semi-structured interviews were conducted. In the following chapter, the method, the results and the data structure of the existing data set collected by ClimbAX will be discussed.

2.1 Contextual Semi-Structured Interviews

2.1.1 Method

To gather requirements for the design of the interactive visualization platform and mobile web application we decided to conduct contextual semi-structured interviews (Lazar, Feng, & Hochheiser, 2010, p. 184). The aim of the interview was to understand users' needs and concerns. Contextual interviews at this early stage related to HCI research are used to identify specific context of a problem and technologies. By asking interviewees to demonstrate how they solve a problem instead of explaining it, these interviews are a good possibility to illustrate aspects of problems. The semi-structured approach was chosen because it is more flexible and adaptable and gives more room for interaction between interviewee and the interview moderator.

2.1.2 Procedure

The interviews were conducted from February 9 to 13 in the therapeutic climbing centre in Weinburg (STKZ Weinburg), Lower Austria. Climbing athletes aged from 14 to 44 years were interviewed. The interview guide was divided into different parts, which are further discussed in detail. Audio records and handwritten notes were taken during the interviews. The interviews took between 12 and 42 minutes. The interviews were conducted in Lower Austrian dialect. The cuttings from the audio records are translated from Lower Austrian dialect into standard German and furthermore into English.

2.1.3 Study Design

The first part of the interview was an introduction to the subject of the thesis and procedure of the interview. Secondly, different demographic data of the interviewees were collected: Age, training level, climbing since and experiences with wearable devices. The main part of the interview was the detection of requirements for the developed system, which contains core subjects of the specific domain:

- Usage and experience with tracking books/logbooks and experience with other health and fitness applications or wearable devices
- Analysis of the existing visualization dashboard of ClimbAX
- Identification of the preferred device or platform for climbers
- Giving Interviewees examples of other visualization techniques to identify established visualization techniques (cf. Figure 2)
- Goal-Setting and Motivation: Find motivational factors and get insights into climbers goals

The interview guideline can be found in the Appendix A.

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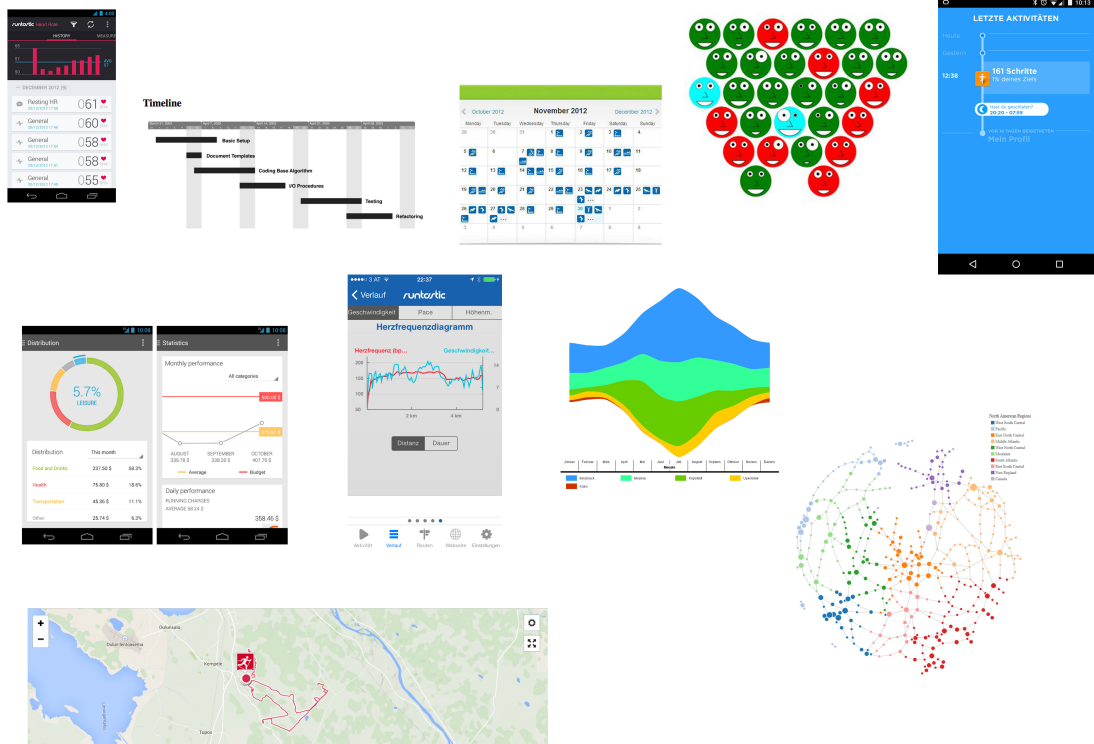


Figure 2: Examples of different Visualization Techniques
First row from left to right: a) Bar chart b) Timeline c) Calendar d) Glyph-based Visualization e) Time Series;
Second row from left to right: f) Donut Chart g) Line Plot h) Themeriver;
Third row from left to right: i) Map j) Node-link diagram

2.1.4 Participants

The interview was conducted with the following people of the target group:

- Male, 14 years old, climbing since the age of 7 years, professional climber – climbing competition group, student of a sports high school in St. Pölten, Lower Austria, smartphone and tablet, no applications used (P1)
- Male, 26 years old, climbing for 6 years, professional climber, fitness coach and climbing coach, smartphone and tablet, no applications used (P2)
- Female, 44 years old, climbing for 3 years, advanced climber, employee, smartphone, heart rate watch (P3)

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- Male, 35 years old, climbing for 4 years, advanced climber, engine driver, smartphone, Runtastic smartphone application for running and cycling (P4)
- Female, 44 years old, climbing for 5 years, advanced climber, accountant, smartphone, *Sportstracker* Android Application for running (P5)

Afterwards, the collected data were compared, similarities identified and summarised. This summary shall now be presented as results.

2.1.5 Results

The key findings of the contextual semi-structured interview are classified into subjects:

Usage and experience with tracking books/logbooks and experiences with other health and fitness applications or wearable devices: Two out of five interviewees use smartphone applications to track and log their physical activities of running and cycling. None of the participants use any applications for tracking climbing activities. One of the five people uses an analogue calendar to track their physical activities by noting information such as altitude, distance, location, and duration. Interviewee P2 logs his special climbing routes in the form of an analogue book, where only special routes and climbing days are noted.

“I use a book; it is a sort of logbook for special climbing routes and days. I log the length of the track, the hardest grade² and the personally achieved goal based on grade. The emotions are also part of my documentation. Besides, I also draw mountains, the routes and also put photographs into the book. I once drew the Dachstein South wall and highlighted the route I wanted to climb. And I can tell you every move from the Raggey Route I climbed in 2009.” (P2).³“

“If I started to track my climbing routes based on a book, I would note the date, my climbing partner, the amount of routes I climbed, grades, different comments and notations, how much I have to rest and also do some documentation of my

² Climbing routes are typically ranked according to their difficulty using established grading schemes like the internationally recognised French grading system for sports climbs or the Hueco „V“ grading system for boulder problems. (Fyffe & Peter, 1997)

³ In this chapter, the cuttings from the audio records are translated from Lower Austrian dialect into standard German and furthermore into English.

2 Problem Analysis

daily condition [...] but I would only note very special or bad climbing days, not just all in that level of detail.” (P5)

Interviewee 4 only uses photogs to log his climbing sessions and mountaineering days.

Analysis of the existing visualization dashboard of ClimbAX: All five participants own a smartphone, but only two of them use some health and activity tracking applications. The different visualization techniques designed by ClimbAX were the basis for the interview to find trends and requirements for the analysis and representation tool. The parameters defined by ClimbAX called „moves,“ „total session duration“ and „total session climb time“ were identified as important by the target group. Different combinations and new visualization possibilities could be identified in the course of the interviews:

“The number of the moves is relative because it depends on the length of climbing routes. But it could be interesting if I could compare it to my physical condition. I give you an example. When I go cycling for 30km and my physical condition is good compared to a bad cycling day, completing the same distance, it would be interesting for me to know, why I could not perform equally in the last training. The same phenomena can be applied to the sport of climbing, when my joints hurt and I can get the number of moves from the system, I can identify my limits. So it is a good possibility to compare it with previous climbing sessions.” (P4)

“I want to see every route I climbed, but I don’t need the accurate information about the duration of one climb. But it could be interesting to see the time I am on the route and between each route I climbed during the session. Also the visualization of the distribution of the power of right and left hand is important for me because sometimes it is the key to success. It could be interesting to know the total climb time because if I do endurance climbing, I consecutively climb easier routes as much as possible. So the ratio between climb and static time could be interesting. And the next time I do the hard routes, where I am shorter in the route compared to my last training session, it is more intensive.” (P5)

“Also the trends and how regular I climb over a long period is attractive to me. Lines to show trends are a good form of visualization.” (P5)

„When I go climbing I will analyse the number of routes I climb, the grade of the route, do I climb hard routes on a day, how often I rest during the climb. Because if I know the time and maybe the amount of resting, I can analyse if my endurance has become better.” (P5)

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The researchers of ClimbAX integrated a visualization illustrating the balance between the left and right hand related to the parameters power, control and stability. A screenshot of the visualization techniques of ClimbAX's system can be found in Appendix D. All interviewees confirmed the importance of a balance between the left and the right hand. So the visualization was ranked as very important for the analysis.

The possibility to add notes and emotional information to the route and daily condition could be a feature that was commented by interviewee 5. Based on the notes of person 2 and the described training protocol of person 1, the importance of keeping emotional information to climbing routes and days could be identified.

Difficulties could be realised in the comprehension of visualization techniques and wording of parameters and titles used in the dashboard design. The star plot and the skill score number as well as the visualization of the number of climbing days caused problems (cf. Figure 1 - combined visualization of line plot and bar chart). Five out of five interviewees criticised the lacking knowledge of the parameter „Control“. The parameters Power and Stability defined by ClimbAX were ranked as useful. Three out of five participants also liked the possibility of giving tips and useful motivational messages to get better and receive feedback from the system.

Identification of the preferred device or platform for climbers: The preferred platforms of the target group could be identified as the smartphone for giving an overview of the climbing data and the desktop device for analysing detailed information. One interviewee argued that he preferred the analysis of the data on the smartphone application while participant 1 wanted to inspect the data on the desktop device. A common view amongst the interviewees was that they tend to review their data at home. No participant preferred the analysis of data directly after climbing.

Giving interviewees examples of other visualization techniques to identify established visualization techniques: To identify the most understandable and common visualization techniques a summary of different application views including data visualizations was presented to the target group.

2 Problem Analysis

The following list shows the detected and not detected types of the presented visualizations:

- Bar chart ✓
- Line plot ✓
- Pie chart / Donut Chart ✓
- Map ✓
- Calendar ✓
- Time series ✗
- Timeline view ✗
- Themeriver ✗
- Glyph based visualization ✗
- Node-link diagram ✗

✓ detected: All five interviewees can interpret the visualization type at the first moment.

✗ not detected: Interviewees cannot interpret the visualization type at the first moment and have to inquire.

After the explanation of the unknown visualization types, the participants were able to understand those views. Participant 5 found a use case for themeriver visualizations, for instance, illustrating quantity of rainfall in comparison to different regions of a country.

Goal-Setting and motivation: Find motivational factors and get insights into climbers goals: Goal-setting and motivation within the context of climbing were defined as individual process of each climber. All subjects defined their goals based on climbing grades. Besides the two professional climbers, the advanced climbing group strived for the grade of 6. The motivational aspect of sharing data identified by Munson et al. (2012) and Michie et al. (2011) could not be confirmed based on the answers of the target groups.

“I don’t compare myself with others. But if I get a new route, and a friend of mine also does this specific route, I communicate with him and we talk about the moves and the crux.” (P2)

“The sport is only for my wellbeing, and I don’t care about other athletes.” (P3)

Giving tips and providing forms of feedback by textual elements, highlighting of parameters or showing trends and patterns were identified as important elements in the motivation and self-reflection process.

2 Problem Analysis

“Yes, if the system could give me tips, it would be a good feature. I know that my right hand is a little bit weaker, and if the system gave fair warnings about how I can improve this disbalance, it could be very helpful”. (P5)

“Tips could be a good possibility to improve my climbing skills.” (P3)

The interviewees addressed an overall interest in the usage of wearable devices for climbing. Person 4 emphasised the necessary simplicity of the usage of the application and also of the data communication of the wearable device and application or online tool.

During the domain problem level (Munzner, 2009), based on the four level nested model of Munzner, requirements were identified by conducting the semi-structured contextual interview. The list below presents user requirements for the target domain climber.

- (R1) The climbers need to gain quick and unambiguous insights. Thus, the interface, the navigation concept and the visualizations should be easy and simple to use.
- (R2) An overview of tracked data and manual input possibility should be provided by the mobile web application. For detailed information, the user can analyse data on the desktop analysis and presentation tool.
- (R3) The system should present information on grade, date, number of routes, comments, resting time, documentation of daily condition, number of moves, total session duration and total session climb time.
- (R4) A combination of the number of climbs, the time in the route, the time between climbs as well as the grade of the routes has to be presented to the user to gain the possibility of analysing physical condition improvement.
- (R5) On the one hand the climber should be able to analyse and explore the data over a long period of time to analyse improvements of climbing and on the other hand get detailed information about climbing data in terms of routes and time on the route.
- (R6) The climber should be able to manually add comments and daily condition to special routes of one climbing day by integrating input fields into the user interface.
- (R7) The system should be able to give tips and motivational messages to the climber to get feedback.
- (R8) The climber should be able to analyse the balance between left and right hand.

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- (R9) Bar charts, line plots, pie charts, maps and calendar visualization techniques should be used to present climbing data.

The above-mentioned requirements were the basis for the design of the system for climbers, developed in the course of this thesis. The next chapter 2.2 described the data detected of the ClimbAX sensor. Also a categorization of the data type is part of this chapter.

2.2 Data from wrist-worn Device ClimbAX

The data shown in Listing 1 was made available by the team of ClimbAX in the form of a JSON file. Detected by the accelerators, the data is scored and normalised. The data detected by the accelerator can be categorised as time-oriented and multivariate (Aigner, Miksch, Schumann, & Tominski, 2011, p. 63f). A form of linearity is given based on the time-oriented sequences of the climbing events, more precisely climbing days (Aigner et al., 2011). The collected data can be defined as discrete, interval-based time sequences. Also, tracked routes can be seen as quantitative, linear and ordered events. The data can be categorised as single granularity because every time value is given in seconds. The JSON data consists of different information such as the beginning and end of a climbing session, this way, the data can be categorised as a span and an interval relating to time primitives. Another important aspect when considering time-oriented data is the determinacy. The given data can be categorised as determinate because of the knowledge of all temporal aspects. The JSON data is temporal and static. A summarised overview of the categorization of the data, based on Aigner et al. (2011, p. 66), can be seen in Figure 3.

JSON Data – Categorisation

Time	Scale	discrete	Data	Scale	quantitative
	Scope	interval-based		Frame of reference	interval-based
	Arrangement	linear		Kind of data	events
	Viewpoint	ordered		Number of variables	multivariate
	Granularity	single	Data & Time	Internal Time	temporal
	Time primitives	interval, span		External Time	static
	Determinacy	determinate			

Figure 3: Categorisation of the Detected Data by ClimbAX Sensors

The ClimbAX System measures every move and splits sequences of moves into climbs. Start time and stop time of each climb and duration of each climb are reported. Also, the time of resting in the route is part of tracked information. Power, control, stability and speed are parameters which are defined by Ladha et al. (2013). These variables are used to evaluate the moves the climber makes

2 Problem Analysis

as well as how the athlete holds each body position. These variables are reported for the left and right hand. Also the number of moves the climber makes is part of the output data of the sensors.

Based on this categorisation the collected data set of ClimbAX is analyzed and described. The session data is grouped in climbs and sessions. A session can be defined as a climbing day containing different numbers of climbs. During the climbing day the climber completed different climbs. Analyzing the data structure of the JSON each session has an array of climbs. An example of the time-oriented data set is shown in Listing 1.

```
"SessionData": [
  {
    "user_id": 1,
    "climbingWall_id": 7,
    "climbingWall_name": 7,
    "id": "1",
    "leftdevice": "1",
    "rightdevice": "2",
    "Climb": [
      {
        "session_id": 1,
        "id": 1,
        "startTime": "2013-01-01 09:10:03",
        "stopTime": "2013-01-01 09:11:10",
        "staticTime": 18.55383963,
        "controlLeft": 0.4617139063,
        "controlRight": 0.9713178124,
        "numberMovesLeft": 24,
        "numberMovesRight": 20,
        "powerLeft": 3.170994801,
        "powerRight": 9.502220488,
        "speed": 0.344460805,
        "stabilityLeft": 4.387443597,
        "stabilityRight": 3.815584571,
        "climb_score": 1.245
      }
    ]
  },
  {
    "startDate": "2013-01-01 09:10:03",
    "stopDate": "2013-01-01 09:33:45",
    "durationSecs": 1422,
    "session_score": 2.356
  }
]
```

Listing 1. Data structure of ClimbAX sensor in JSON

2 Problem Analysis

Table 1 shows the description of the variables of the JSON data. Based on the results of the contextual interviews and the derived requirements, the following variables are interesting to visualise.

- Power, Stability and Control variables for the left and right hand (R8)
- `numberMovesLeft/numberMovesRight` (R3)
- `durationSecs, staticTime startTime/stopTime` (R3)
- `climbingWall_name, startDate/stopDate` (R4)
- `climbScore`

2 Problem Analysis

Variable	Description	Scale type	Values	Example
user_id	Each user, registered for the ClimbAX system	discrete	1 to N (grows with the number of users)	1
climbingWall_id	Id of a known climbing wall	discrete	1 to N (grows with the number of users)	7
climbingWall_name	Name of the climbing wall			Raggey Route
id	Serial number of device	string	Serial number of the device	17-12345
Leftdevice/ rightdevice	Is the device for left or right hand	string	LEFT/RIGHT	LEFT
session_id	Id for each climbing session	discrete	1 to N	1
id	Id for climb within the session	discrete	1 to ...	2
startTime/ stopTime	Start and stop time of this climbing sessions – including resting time	discrete		2013-01-01 09:10:03
staticTime	Summarised resting time on the route	discrete	seconds	18.55383963
controlLeft/ controlRight	The ability to transistion smoothly between holds – for the left and right hand	normalized value	0 to 10	0.4617139063
numberMovesLeft/ numberMovesRight	Number of moves of the left and right hand	discrete	1 to ...	24

2 Problem Analysis

powerLeft/ powerRight	The ability to transfer isometric strength into a move for the left and right hand	Normalized value	0 to 10	9.502220488
speed	Defined as timing observation. In most cases, completing a climb in the shortest possible time is desirable. – normalized value	float	0 to 10	0.344460805
stabilityLeft/ stabilityRight	The ability to remain composed while holding onto holds - for the left and right hand	Normalized value	0 to 10	4.387443597
climb_score	Score of one climb depending on the parameters controlRight, controlLeft, stabilityRight, stabilityLeft, powerRight, powerLeft, speed	float	0-10	1,245
startDate/ stopDate	Start/stop of the climb within the session (Just climbing no rest)			2013-01-01 09:10:03
durationSecs	Total duration of a climb seconds			123
sessionScore	Score of the whole session depending as mean of the climb_score Normalised against all the session scores in the database.	float	0-10	2.365

Table 1: Listing of the Variables detected by the ClimbAX Sensor

2 Problem Analysis

The developed requirements derived from the interview and the analysis of the data structure indicate that the design study in this thesis explores new fields in designing and developing systems for this special domain. Insights into the needs of climbers were given by conducting the contextual interviews. Therefore, the next chapter aims at exploring existing applications and visualization techniques in the sector of sport climbing.

3 State of the Art

In the following, research related to different aspects of the thesis and the identified requirements of the domain based on the contextual semi-structured interview are discussed. The research was done in the field of quantified-self systems for tracking human behaviour and physical activities via wearable devices, native applications, and web platform as analysis tools and tracking books for rock climbing. Also, an analysis of existing products in the field of wearable devices for tracking personal data is part of the state of the art.

3.1 Wearable Devices for Daily Routines and Tracking Human Behavior and Physical Activity

Commercially available devices, such as Fitbit (“Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker,” 2015) and other wearable devices (“UP - Jawbone UP24,” 2015; “Runtastic Orbit - Aktivitäts, Fitness & Schlaf Tracker,” 2015) have been designed to fit into users’ daily life. Tracking steps, physical activities, sleep behaviour or food intake are the main features. These trackers usually come with custom mobile applications where the user can see their activity history, set activity goals and share their data with others. In the process of changing the behaviour, the reflection stage is a fundamental component and facilitates an understanding of the represented data and reflecting personal behavior patterns. Several works have been conducted to formalise the reflection process in this area. Li et al. identified six questions for reflection (Li, Dey, & Forlizzi, 2011): Status (what is my situation now?), History (what was my situation in the past?), Goals (what do I want to achieve in the future?), Discrepancies (how does my status compare with my goals?), Context (what affects my status?), Factors (how are different attributes related?)

Consolvo et al. (2012) have explored mobile wellness applications to encourage people to be more active in their daily lives. In this domain the team of Consolvo has built and tested several prototypes: for example *Houston*, *UbiFit* and

3 State of the Art

GoalPost. Houston was designed to track step counts and share them with friends or family members and so create a competition with regard to being fit and healthy (Consolvo, Everitt, Smith, & Landay, 2006).

The second analysis concerning developing technology to support health and wellness focused on *UbiFit* (Consolvo, Klasnja, et al., 2008). UbiFit is a system based on an application on a mobile phone accompanied by sensing and interfering to detect activities (cf. Figure 4). This system promotes self-reflection by providing personal awareness of all of the physical activities that a user performs over a week and supports by providing rewards when a weekly physical activity goal is achieved. This application allows people to visualize their individual physical activity in the form of a garden that grows the more activity the user has performed.



Figure 4: UbiFit Garden Application (Consolvo, Klasnja, et al., 2008). This application is designed to motivate individuals to do regular physical activities and integrate exercises into everyday lives. a) at the beginning of the week small butterflies indicate recent goals; the absence of flowers means no activity this week b) a garden with workout variety; c) the display on a mobile device – the large butterfly indicates this week's goal was met of the individual.

3 State of the Art

GoalPost helps people incorporate regular and varied physical activity into their everyday lives (Munson & Consolvo, 2012). The system was designed to support goal-setting by encouraging users to set two goals per week. Rewards like giving users ribbons and trophies help to motivate them to achieve their weekly goal. A self-monitoring approach via an activity journal encourages users to record their activities and set their goals and share their performed activities via social networks. The *GoalPost* interface design can be seen in Figure 5.



Figure 5: *GoalPost* Overview (Munson & Consolvo, 2012): a) main screen shows progress bars for each activity category of user's goals b) the Goal screen shows how the user is doing with respect to the goals in a week c) the user's trophy visualization

Other aspects of these technologies along development in sensing technology itself and the design of quantified-self applications research has been made in how design affects activity and behaviour (Consolvo, Libby, et al., 2008; Tudor-Locke, 2002), how to use visualization to motivate activities and provide awareness (Consolvo, Klasnja, et al., 2008; Lin et al., 2006), how feedback is understood and used (Li, 2009) and how such technologies should be evaluated (Klasnja, Consolvo, & Pratt, 2011). Consolvo et al. (2009) have also developed a set of design guidelines for systems that support health behaviour change.

Munson (2012) proposed a spectrum of these devices ranging from *reflective technologies*, where systems support people in gaining insights into their existing behaviour and achieving a behaviour change, to *persuasive technologies*.

Persuasive systems push people to do something without their knowledge about their behaviour or in a way that overrides their autonomy.

Persuasive technologies employ different strategies for influencing behavior and activity such as described by Fogg (2002). These seven strategies, which influence the behaviour of a user, are: *Reduction, tunneling, tailoring, suggestion, self-monitoring, surveillance, and conditioning*. In quantified-self applications *self-monitoring* and *conditioning* are the most noticeable. *Self-monitoring* technologies allow people to monitor themselves to modify their behaviour and achieve a pre-determined goal. *Conditioning* technologies make use of operant conditioning. This can be implemented in the form of positive reinforcement to the user in order to increase target behaviour.

In the field of rewards and motivational messages, the notion of Michie et al. (2011) could be employed. Identified by Consolvo et al. (2009), setting explicit goals for different periods of time is very effective. Nearly all of the systems support a data sharing option on websites or social network platforms, which is a valuable strategy found out by Munson et al. (2012) and Michie et al. (2011).

Discussion

These studies provide important insights into different products available on the market that are effective in improving the level of activity simply through providing visualizations to the user. Collectively, these studies outline a critical role for detecting different physical activities besides walking or running (Consolvo, 2012, p. 210f). Other activities, such as tennis, biking or using elliptical trainers might be tracked as steps and so distorts the “active time” metric. A number of studies have found that the process of feedback systems and design systems support health behavior changes.

Different applications to encourage people to be more active in their daily lives have to be developed such as *Houston*, *UbiFit* and *GoalPost*. Several recent studies have begun to examine a categorisation in self-monitoring and conditioning technologies. Different papers can be found in the field of evaluation of such systems. Drawing on a range of sources, the authors set out the integration of wearable devices into users' daily life by providing feedback via native applications and web platforms. The next chapter focuses on wearable devices which detect different sports and also provide different features of training plans and guidance during physical activities.

3.2 Wearable Devices for Tracking Physical Activity in Training Sessions

By tracking other physical activities automatically the tracker MisFit Flash (“Misfit Flash | Sporty Fitness + Sleep Monitor,” 2015) can detect running, walking, biking, basketball, soccer, tennis and swimming. Other commercially available devices, such as *Adidas FitSmart* (“adidas miCoach,” 2015a) and *SmartRun* (“adidas miCoach,” 2015b), as well as tracking systems by Garmin (“vívofit 2 - Fitnesstracker | GARMIN | Deutschland,” 2015), *Polar* (“Polar Loop und V800,” 2015) *Nike Fuel Band* (“Nike Fuelband,” 2015) or numerous other devices (Ramirez, 2015) are effective for improving the level of activity. By using these tracking devices, the users can check their training level and performance via native applications or a web platform.

These fitness trackers try to monitor day-to-day activities in addition to workouts. While these devices put great emphasis on steps, calories and heart rate, they do not tell athletes if they are working out efficiently or correctly. Adidas miCoach provides guidance supported with audio coaching and vibration (“adidas miCoach,” 2015a). The Moov “wearable coach” teaches athletes how to exercise properly (“Meet Moov,” 2015). The system provides a near-constant feedback loop by turning data collection into real-time coaching. Different sports like running, biking, swimming, cardio boxing, and weight training can be detected automatically.

Hogenboom (2014) developed a digital coach for runners that can give haptic feedback via vibration and visual LED. This system is built in the form of a wristband with GPS module. The digital coach, developed in this paper, bases on the model of DiSC (“DiSC Profile - The DiSC personality test explained,” 2015) or Five Factor Model. This means that the coach takes on different personalities like being strict and dominating or relaxed and absent depending on the athlete’s behaviour.

Fritz et al. (2014) conducted a study “in the wild” to understand how practices evolve over long-term naturalistic use. 30 participants who had been using wearable tracking devices for physical activities for between 3 and 54 months were the main target group of the study. The main findings in terms of designing personal informatics technologies for long-term health and fitness support are the following. Tools should offer explicit motivation for the maintenance of practices or achievements to ensure a durable behaviour change. Among long-term users, the engagement with social networks has to be supported to provide a source of motivation. By designing personal informatics technologies designer should find

ways in which users can measure and track activities over time. And subsequently, also provides an integration of different sensing technologies into the overall ecosystem for example tracking more specific physical activities besides general data (e.g. detecting steps). In terms of supporting the evolution of reward, the system might allow users to specify a reward in “real world”, besides the built-in system.

Some other sport assessment tools focus on technical skills of the athlete by providing detailed information on the quality of the particular activities, for example golf swings (Grober, 2010) or automatic assistance for swimming (Bächlin, Förster, & Tröster, 2009).

Discussion

Devices of Polar, Garmin, Adidas and Misfit can detect various sports and also provide different features for guidance during and after the training. The effort and influence of assessment features have been explored in studies by Hogenboom and Adidas. The focus of tracking physical activities over long-term naturalistic use were analysed, and some guidelines were identified for health and fitness support. Assessment tools that focus on the athletes’ skills and the quality of movements were found in golf swings and swimming. A lot of research has been done in the field of quantified-self for tracking daily activities of the user and only little work on wearable devices which support the athlete during and after the training session. Figure 6 summarises the different areas of research of tracking physical activities and behaviour integrated into users’ daily lives. In the next chapter different native applications and web platforms are discussed as analysis tools, focusing on the type of visualization of personal quantified data.

Wearable Devices for Tracking Physical Activity in Training Sessions

Commercial products

MisFit Flash
adidas FitSmart & SmartRun
Garmin vivofit 2
Polar Loop & V800
Nike FuelBand
Adidas miCoach
Moov

Research work

Digital Coach - haptic feedback via vibration and LED (Hogenboom, 2014)

Study „in the wild“ long-term naturalistic usage of wearable tracking devices for physical activities (Firtz, Huang, Murphy, & Zimmermann, 2014)

Technical skills and quality of movement in Golf swings (Grober, 2010) and swimming (Bächlin, Förster, & Tröster, 2009)

Wearable Devices for Daily Routines and Tracking Human Behavior and Physical Activity

Commercial products

Fitbit UP
Jawbone UP
Runtastic Orbit
Misfit Shine

Research work

Houston (Consolvo, Everitt, Smith & Landay, 2006)

UbiFit (Consolvo, Klasnja, et al., 2008)

GoalPost (Munson & Consolvo, 2012)

Categorization

Reflective & Persuasive technologies (Munson, 2012)

Behavior Change

Self-reflection & Conditioning (Fogg, 2002)

Motivation & Goal-Setting

How design affects activity and behavior (Consolvo, Libby, et al. 2008)

How to motivate and provide awareness (Consolvo, Klasnja, et al., 2008), (Consolvo, Klasnja, McDonald, & Landay, 2009)

How feedback is understood and used (Li, 2009)

Rewards and motivational messages (Michie et al., 2011)

Data sharing & sharing opportunity on websites of social network platforms (Munson & Consolvo, 2012)

Evaluation

Evaluation for health behavior change in HCI Research (Klasnja, Consolvo & Pratt, 2011)

Figure 6: Overview State of the Art

3.3 Native Applications and Web Platform as Analysis Tools

Fitness and health wearable devices available on the market offer web platforms or/and native applications for users including sophisticated visual representations. Several visualization techniques represent users' data over time such as sleep behaviour, nutrition habits or the amount of physical activity. These systems also try to interpret the data and give explicit insights.

Brüel Falmark combined the fields of data visualization, quantified-self and app development to create an approach developing quantified-self applications that avoid the problems of today's data representation in quantified-self apps (Brüel Falmark, 2013). Based on the state of the art research, problems in data visualizations of different commercial products (Endomondo, Runtastic, FitBit, Just 6 Weeks, Accupedo, Nike+, Sleep as Android, SleepStats, Sleep Cycle alarm clock) have been identified by Brüel Falmark. The recurring problems are the unexplained icons, missing axis titles and values, too less white space and too small text elements. He conducted an early validation test with a number of different data presentations found in commercial products. During the testing phase, he identified six categories of problems: icons, colours, information overload, size, comparison and explanations. These results formed the basis for the developed prototype of a quantified-self application by Brüel Falmark.

Packer et al. (2014) performed a preliminary survey on personal fitness devices with active users of such systems (cf. Figure 7). A directly manipulated interface to visualize and annotate personal fitness data was the basis for the pilot study in-lab with five expert users. The main features of the prototype were to annotate their data, correct and replace data and compare activities. The results of the pre-study survey have shown a trend towards manipulating and adapting interface elements and data representations for analysing. In the developed system in the course of this research paper users can label activities by adding comments to their activities. To provide the possibility to fill in missing data, a drag-and-drop duplicate feature was implemented in the prototype. Users can select an interval, click and so modify the magnitude of the data via drag-and-drop. The final pilot study has presented the importance of preservation, the provenance of data and the ability to share tracked data.

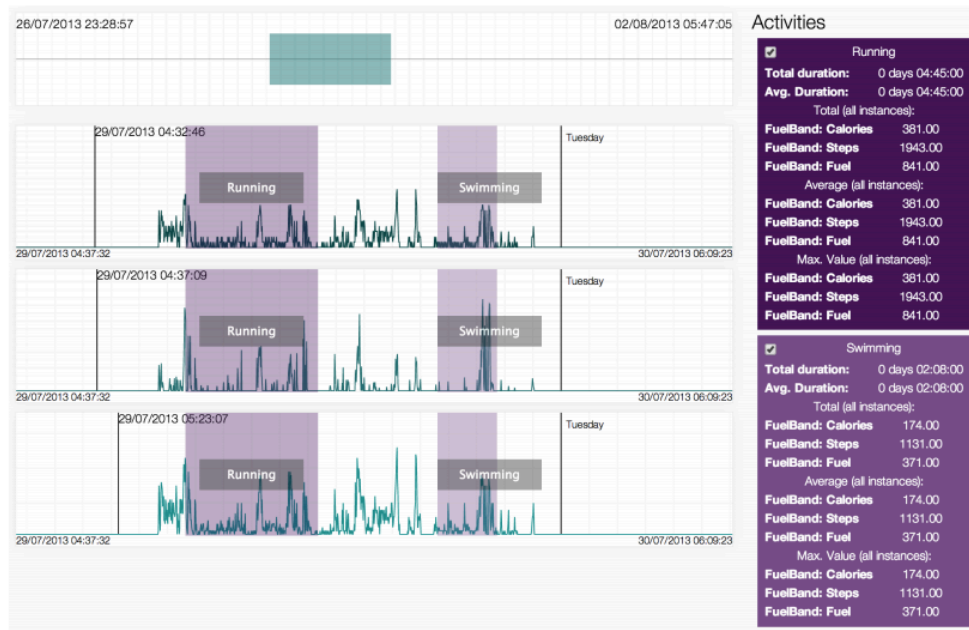


Figure 7: Multiple data sources are positioned in the center of the interface. A time viewport at the top and multiple activities to the right are also part of the system. (Packer et al., 2014)

In their workshop paper, De Croon et al. discussed how they had applied a user-centered, rapid-prototyping methodology to design and evaluate a quantified self dashboard for triathletes (De Croon et al., 2014). By taking into account different quantified-self barriers, identified by Li et al. (2010) and Choe et al. (2014), they designed a dashboard and evaluated it with 25 triathletes and 14 regular persons. Li et al. (2010) introduced a stage-based model of personal informatics derived from analysis of the survey and the interview data. This model concludes five stages: *Preparation*, *Collection*, *Integration*, *Reflection*, and *Action*. In each stage different barriers can occur, and a barrier in one stage can cascade to later stages. The *preparation* stage refers to the start of collecting personal information. The problem in this stage appears when users choose the wrong information to track or when users select an inappropriate tool that does not satisfy users's needs. These incorrect selections can lead to data loss. The *collection* stage is the time when users collect their information about themselves. Some problems can occur because of the user's lack of time, lack of motivation or forgetfulness. Other problems refer to the tracked data, because some data are hard to estimate or some data are difficult to find. During the *integration* stage the information is collected, prepared, combined and transformed for the user to reflect on. Here problems may appear if collected data come from multiple inputs, visualizations are scattered or the data collection

is different from what the visualization requires. The next stage in the presented model is called *reflection*. This stage is reached when users reflect on their tracked information. During this stage, a problem might be the lack of time for analysing the data, self-criticism and problems with retrieving, exploring and understanding the information. The fifth stage is the *action* stage when users choose what they are going to do with their understanding of themselves. During this stage people reflect on the information but do not have specific suggestions on what to do next. This above-mentioned barriers were taken into account of De Croon et al. (2014). The results of the study have shown that the applied methodology and a well-designed dashboard can help users to analyze their data. During their rapid prototyping process, they also regarded different design approaches for dashboard design identified by Few (2006). The resulting prototype design of the dashboard for triathletes is presented in Figure 8.



Figure 8: Dashboard Design for Triathletes (De Croon et al., 2014): The dashboard design contains different areas. In the first row, the first part of the dashboard illustrates training intensity divided into the three discipline of a triathlon. A calendar is integrated to provide the possibility to add activities. The third area constitutes as a summary of physical activity. The graphs for personal specifications (second row) and training intensity show the evolution of four values on top of each other, so that a comparison on a daily basis is possible. To show all the times of contests that are done in the selected time period, a line graph is integrated. Clicking on a data point the details of the contest appears.

Choe et al. (2014) identified three pitfalls, which are common to self-tracking including tracking too many things, not tracking triggers and context, and insufficient scientific rigor.

3 State of the Art

Consolvo identified four main forms of feedback: counts, graphs, stylized representations and narrative information (Consolvo, 2012, pp. 227–241). Most physical activity displays use metaphors, charts and numbers to represent physical activity. (e.g. FitBit, Runkeeper, Jawbone). Beside the studies examined by Consolvo, other researchers highlighted the relevance of other forms of visualization techniques. Lin et al. (2006) introduced *Fish 'n' Steps* a virtual fish tank and Consolvo et al. (2009) used flowers to represent physical activity.

An informative art display that visualizes physical activity using abstract art called “Spark” was developed by Fan et al. (2012). They developed five visualization types on different abstraction levels in the form of “Spiral”, “Rings”, “Buckets”, “Pollock” and a bar chart, which can be seen in Figure 9. Also four guidelines for systems that track and visualize physical activity have been derived. “Tools can provide both charts and abstract art to increase engagement with the system over time” (Fan et al., 2012) Second guidelines describes the need of provide choices of different visualization to allow users to customize the data at the level of information they want to. Fan et al. also highlight to integrate visualizations into daily routines by using tables, standalone displays. The system should also adapt the goal to the user’s physical abilities, instead of regulate one number or range as the ideal goal for the users.

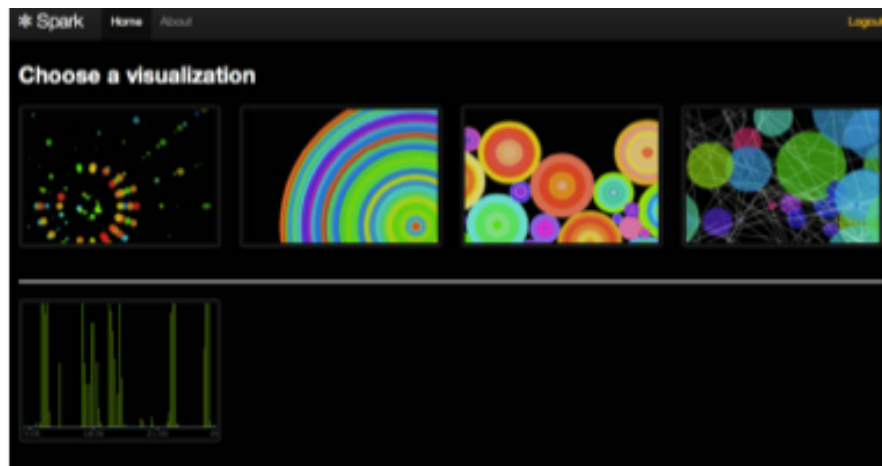


Figure 9: Spark Visualization (Fan et al., 2012): “Spiral”, “Rings”, “Buckets”, “Pollock” and a bar chart are the visualization types used in the Spark main screen. This screen allows users to choose from five different visualizations, four abstract and one bar graph.

Cuttone et al. (2013) have presented a system for Android smartphones that provides an interactive visualization interface for personal data captured by mobile embedded sensors (GPS and Bluetooth). Figure 10 shows the different types of visualization techniques developed in this study. Based on the previous work done by Larsen et al. (2013) “QS Spiral: Visualizing Periodic Quantified Self Data”, a Spiral Timeline and a Bubbles view were used as visualization techniques to provide insight into periodic movement.

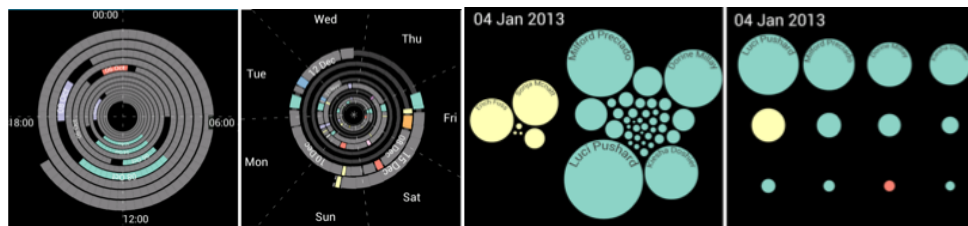


Figure 10: Spiral Timeline and Bubble View (Cuttone et al., 2013) The left panel shows a period of 24 hours and the right one a period of 7 days. The colored arcs illustrate the time spent at points of interest. The next views give detailed information from the social network visualization. Bubbles represent users and the radius is proportional to the social interaction estimation. The colors of the bubbles show social communities.

Cuttone et al. (2014) explored how to facilitate the process of reflection in personal informatics and quantified-self systems through interactive data visualizations. By analyzing self-tracking devices and apps, they identified four heuristics for the design and evaluation of such systems. Make data interpretable at a glance, enable exploration of pattern in time series data, enable discovery of trends in multiple data streams and turn key metrics into affordance for action are the four heuristics developed by Cuttione et al. Dashboard interfaces of specific self-tracking devices such as Fitbit (“Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker,” 2015) and Basis (“Peak Page - Basis,” 2015) were discussed as the state of the art in feedback and reflection support. Also, other domains, such as event-related representations of time series multivariate data in financial analytics are analysed to connect the approaches to quantified-self visualizations. In this paper, it has been discussed how the heuristics could help to do better designs and simplify the self-reflection in tracking systems for personal information.

Choe et al. (2014) have analysed how quantified self trackers explored data and captured 188 screenshots composed of 243 charts and types of graphical feedback. Line charts were the most frequently used, followed by bar charts and custom visualizations.

Discussion

Different problems and obstacles were identified in the field of data visualization for quantified-self applications for desktop and mobile usage. The identification of different feedback possibilities within the applications has been part of the recent studies. Charts, avatars, notifications, narrative and abstract art are summarised and illustrated in Figure 11. Also, different visualization techniques and layouts were part of the research area of quantified-self, which includes interfaces to visualize and annotate personal fitness data or dashboard designs for triathletes. Spiral, Rings, Buckets, Pollock or Spiral Timelines are visualization techniques which are used in quantified-self applications on mobile or desktop devices. Four data visualization heuristics were identified which are 1) make data interpretable at a glance; 2) enable exploration of pattern in time series data; 3) enable discovery of trends in multiple data streams and 4) turn key metrics into affordance for action. All of the approaches concentrate on quantified-self applications independent to the platform or physical activity.

3 State of the Art

Native Applications and Web Platform as Analysis Tools

Dashboard Design



Applying a user-centered, rapid-prototyping methodology with quantified self: A case study with triathletes
De Croon, R., De Buyser, T., Klerkx, J., & Duval, E. (2014)

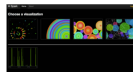
QS-Spiral



QS Spiral: Visualizing Periodic Quantified Self Data
Larsen, J.E., Cuttone, A., Jørgensen, S.L. (2013)



A Mobile Personal Informatics System with Interactive Visualizations of Mobility and Social Interactions
Cuttone, E., Lehrmann, S., & Larsen, J.E. (2013)



A Spark of Activity: Exploring Informative Art As Visualization for Physical Activity
Fan, C., Forlizzi, J., Dey, A.K. (2012)

Abstract Art



Fish'N'Steps: Encouraging Physical Activity with an Interactive Computer Game
Lin, J.J., Mamykina, L., Lindthner, S., Delajoux, G., & Strub, H.B. (2006)

Graphical Feedback



Designing for Healthy Lifestyles: Design Considerations for Mobile Technologies to Encourage Consumer Health and Wellness
Consolvo, S (2012)

Counts, Graphy, Stylized Representations and
Narrative Information

Figure 11: Overview of Native Applications and Web Platform as Analysis Tools

3.4 Visualization of Multivariate Time-Oriented Data

The basis for the representation of this thesis is formed by multivariate time-oriented data. Several recent studies have begun to examine the use of different types of visualization techniques for such types of data. An overview of multivariate time-oriented data representation techniques identified in the survey of Aigner et al. (2011) was given. Based on this collection, four techniques were extracted as a possibility to illustrate the sensor data of the wrist-worn device for climbers of ClimbAX. The visualization techniques were selected based on the problem analysis conducted in the course of the thesis. The data basis is categorized as multivariate and time-oriented, described in chapter 2. Taking account the identified user requirements the visualization type sparklines, tile maps, silhouette graph and cycle plots were extracted as useful visualizations.

Sparklines are simple, word-like graphics, which can be integrated into the text, shown in Figure 12. The visualization method popularized by Tufte (2006) focuses on an overview rather than giving specific details of the time-oriented data. A seamless integration into a paragraph of text, tables or dashboards is possible. For example, miniaturized versions of line plots or bar graphs can be used to represent data. This form of representation could be interesting for the visualization of motivational messages for climbers and also for enhancing textual elements in the form of overview messages or a summary of climb workouts.



Figure 12: Sparklines Visualization (Tufte, 2006)

3 State of the Art

Health and fitness applications provide representations to show the amount of physical activity. Related to climbing tile maps might be a possible visualization method, which gives users insights into long-term trends in their training data. Tile maps were described by Mintz, Fitz-Simons & Wayland (1997) and illustrate a series of data values along a calendar division. The arrangement as a two-dimensional matrix allows users see the matrix as a whole and identify individual trends for weekdays by looking at the matrix rows and weekly patterns by analysing matrix columns. This structure can be seen in Figure 13.

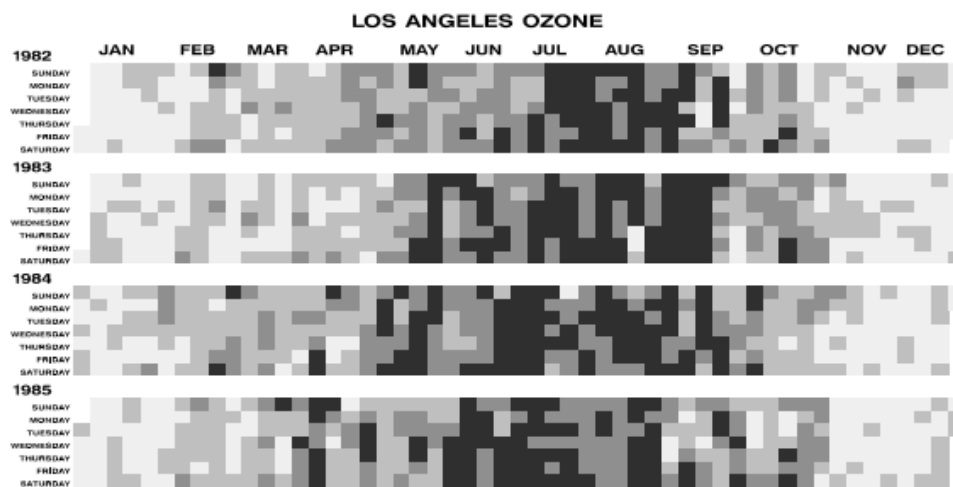


Figure 13: Snippet of a Tile Map (Mintz, D. et al., 1997)

Silhouette Graphs as discussed by Harris (1999) enhance the comparison of multiple time series that are put side by side. This method provides the users with an overview and it could be integrated into quantified-self applications, as shown in Figure 14. By arranging a silhouette graph in the form of concentric circles, periodicities in time can be illustrated.

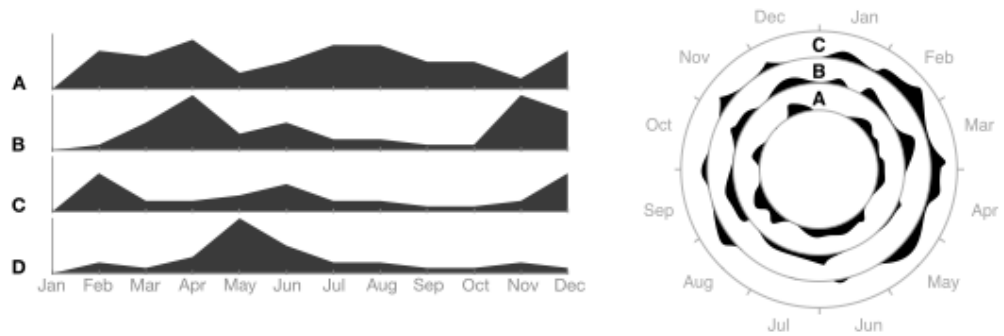


Figure 14: Silhouette Graph (Harris, 1999)

By showing the seasonal aspect as well as a trend component, cycle plots could be integrated (Cleveland, 1993). Individual trends are illustrated in the form of line plots embedded within a plot that shows the seasonal pattern, as illustrated in Figure 15.

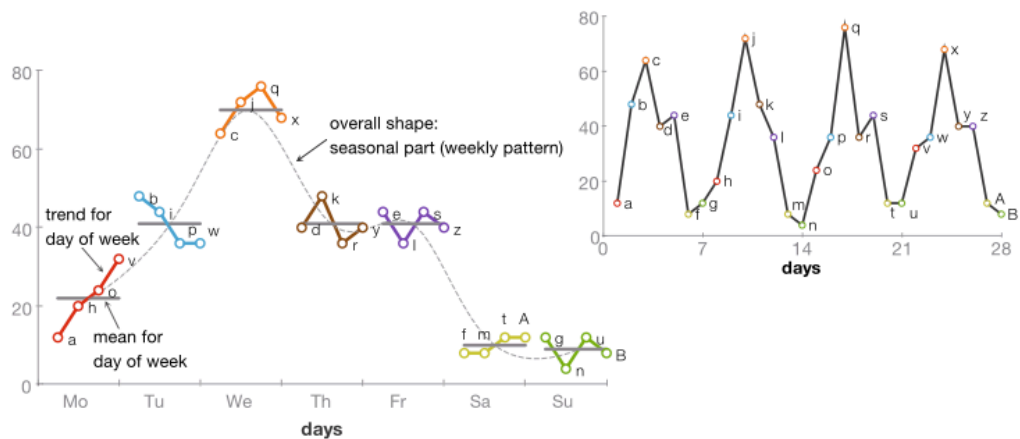


Figure 15: Cycle Plot (Cleveland, 1993) shows seasonal and trend components

Discussion

A number of studies deal with visualization techniques for multivariate time-oriented data. Based on the survey by Aigner et al. (2011) four methods were chosen in the view of the usage in the domain of climbers. Sparklines, tile maps, silhouette graphs and cycle plots were identified as possible approaches for illustrating the sensor data. The identified requirement of giving a long-term insight into the data to review trends and patterns in the climbing activities demonstrate the importance of the visualization method discussed above. Integrating Sparklines in health and sports applications and analysis tools might be a good possibility to enhance motivational messages and to summarise of training days as textual elements with small graphs and visualization. In the following chapter commercial products, which track physical activities during training sessions are analysed.

3.5 Analysis of Commercial Products

More and more products exist on the market that provide different features for tracking food, physical activity and sleep. Only a few wearable devices focus on detecting movement of different sports (running, cycling, etc.) and constitute as self-assessment tools or sports coaches. In the following, an analysis of existing products is conducted, focusing on visualization techniques and interactivity approaches.

Endomondo

Endomondo is one of the most popular quantified-self apps with more than 10 million users (Velazco, 2015). The application is available on four platforms (iOS, Android, Windows Phone, and Blackberry). Different information is shown to the user: duration, distance, average pace, the exercise type, heart rate, calories burned, hydration, minimal and maximal altitude (Figure 16) ("Endomondo – Laufen & Radfahren," 2015). The application allows the user to synchronize the application with a heart rate monitor and also get some live audio feedback while training or running. This application provides different exercise types to be selected before tracking the physical activity. Also, a social networking aspect is part of the Endomondo application with a history of comments, live comments and likes for each activity. A collaborative aspect is also part of the concept of Endomondo by setting goals and sharing them with friends, who can motivate the athlete during the training. This application also provides the exercise type

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“climbing”, but there are no specific parameters adjustable for climbing movement.

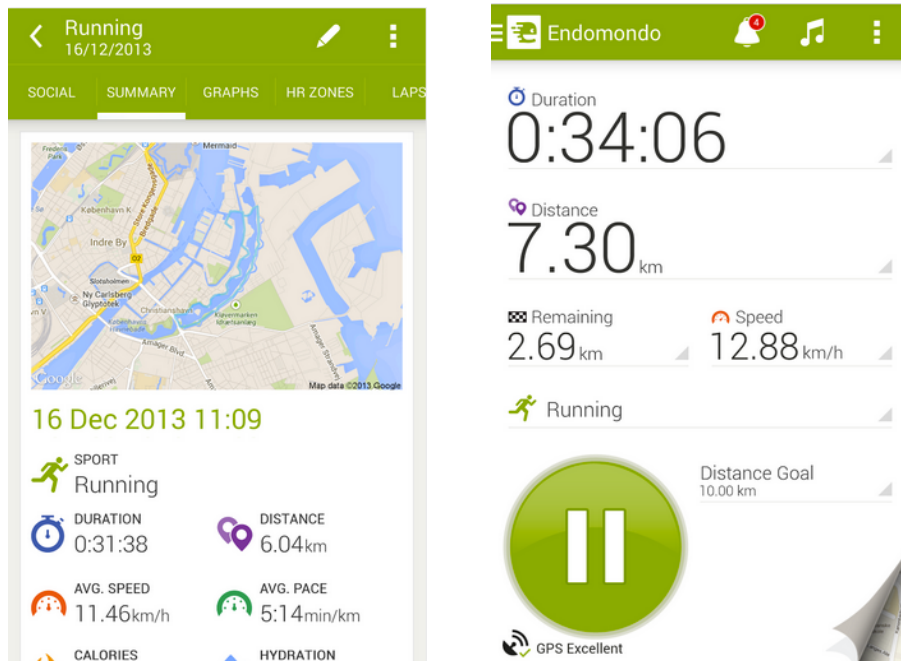


Figure 16: Endomondo Android Application (“Endomondo – Laufen & Radfahren,” 2015)

The online platform provides different forms of information representation on different abstraction levels, seen in Figure 17. A calendar view is part of the layout and provides various icons for finished activities. An interactive map view with the route of the activity and lap time is also part of the analysis tool. The hard facts about the workout are displayed in a textual form and an interactive line graph and bar chart represent a performance view over time in combination with altitude in metres. A toggle element provides a different view on the existing data based on a time and distance representation.

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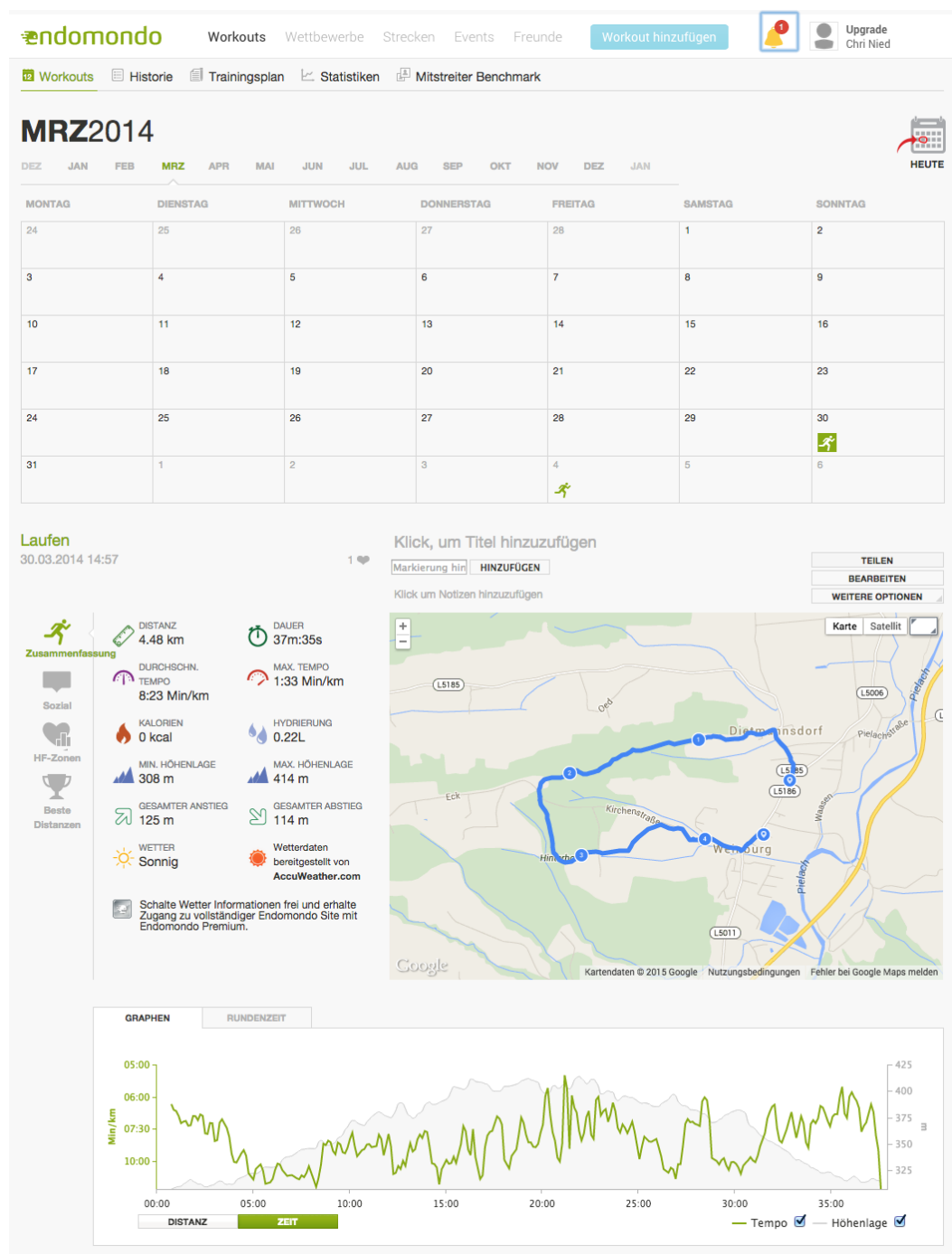


Figure 17: Endomondo Web Platform ("Endomondo – Web Platform," 2015)

Moov

The Moov tracker aims to be more of a fitness friend, a “personal artificial intelligent fitness coach” (“Meet Moov,” 2015). By using a combination of three powerful sensors, Moov tracks whatever it is strapped to and monitors movement accordingly, whether the device is attached to the ankle, wrist or bike pedal. Moov is a mobile software that acts as a personalized fitness coach. It is a wearable tracker for workout beginners and advanced users. The wearable device tells the athlete in real time with a Siri-sounding voice, when, for instance, the rate of the stride is too slow and the force of the athlete’s foot hitting the ground is too high. Five different activities can be tracked: cycling, swimming, running, weight training and cardio boxing. For each physical activity, there are specially designed applications available for iOS or Android. All visualization techniques are adjusted to compare data for each specific sport. Different coaching videos and tips are provided to the athlete via the native applications. For Moov, there is no online platform available to analyse the detected data from the wearable device.

The Android application “Moov Running & Walking Coach” provides lists and some textual feedback visualizations, shown in Figure 18. A summary of the run based on levels is represented via a bar chart. An explanation of the bar chart and a personal motivational message are also part of the visualization concept. During the training session a combination of textual and visual representation is displayed. For instance, the time remaining for the warm-up is represented via a progress bar.

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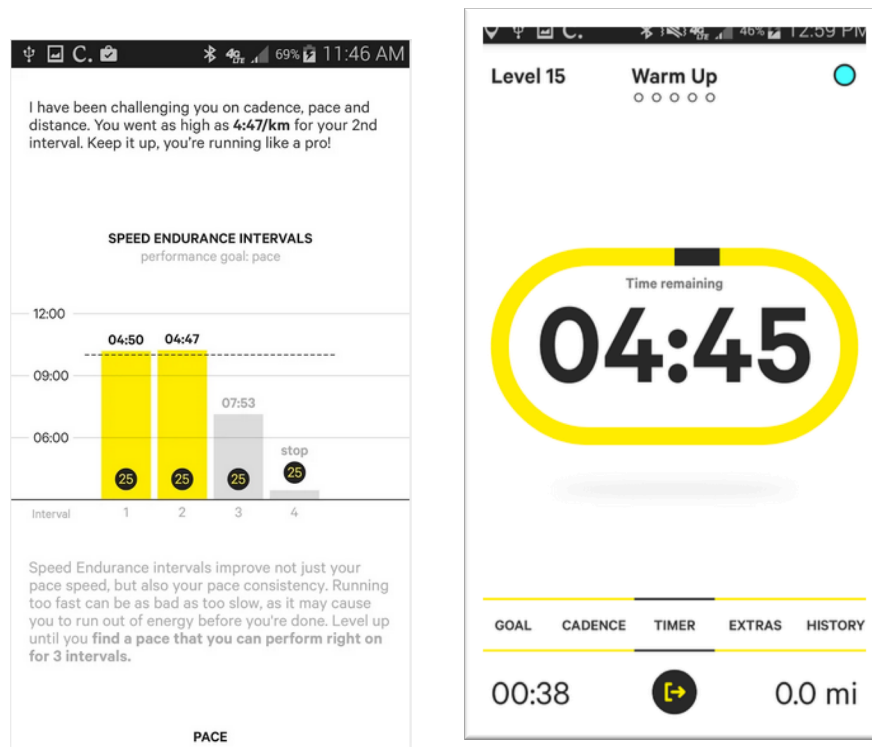
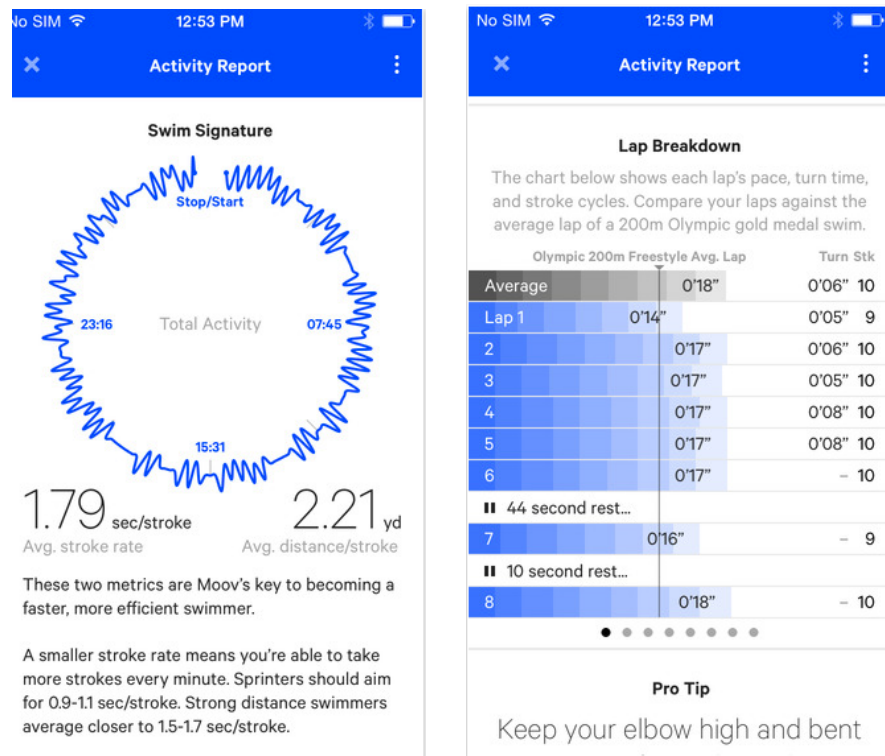


Figure 18: Moov Running & Walking Coach iOS Application (“Meet Moov,” 2015)

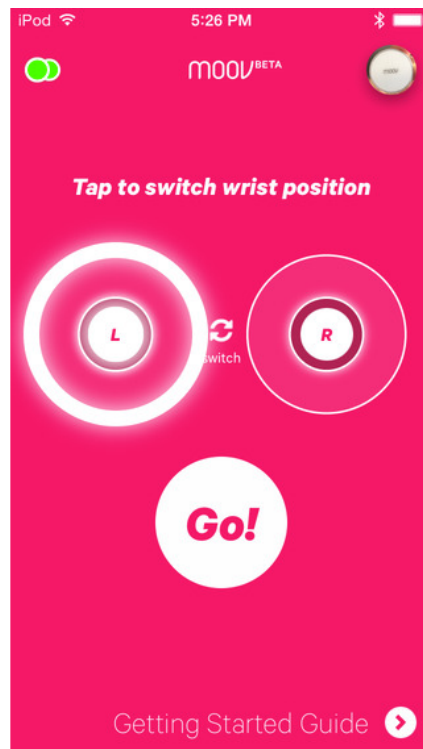
The swimming application provides specific graphics based on the requirements of swim athletes (“Moov Swim,” 2015). There is also an activity report for swimming based on textual and graphical feedback visualizations. The interface design of the application can be analysed in Figure 19. The interface is separated from an overall visualization of the swimming session and also some explanations of the parameters displayed via textual information units. The “Total Activity” visualization is a combination of a pie chart and line plot arranged in a circle. The different laps are visualized via bar charts with textual information. The report also consists of a part which gives the users tips to improve their movement.

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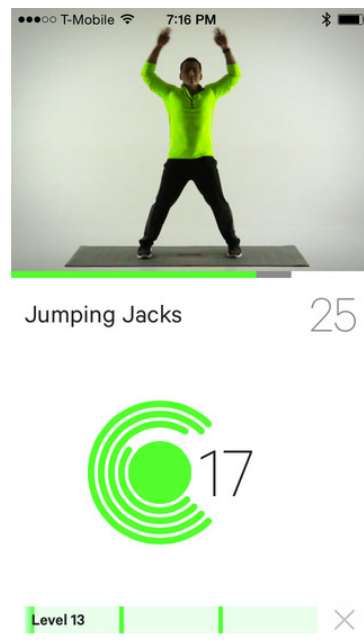
*Figure 19: Moov Swimming iOS Application
("Moov Swim Wearable Coach," 2015)*

Moov offers an application for cardio boxing ("Moov Cardio Punch," 2015). Tutorials and interactive choreographies are designed and help the athletes to improve their moves and punches while training. The choreography is visualized via interactive graphic sequences shown on the smartphone or tablet. Figure 20 displays the interactive graphic elements of the application.



*Figure 20: Moov Cardio Boxing iOS Application
("Moov Cardio Boxing Wearable Coach," 2015)*

An application for a seven-minute workout provides different video tutorials of the exercises and also displays the intensity of the workout and the duration of the different levels via textual information and graphs ("Moov 7 Minutes+ Workout," 2015). These graphical feedback visualization types are modified bar and pie charts, illustrated in Figure 21.



*Figure 21: Moov 7-Minutes Workout iOS Application
("Moov - 7 Minute+ Workout Coach," 2015)*

The application for the sport of cycling is currently not available on the App Store.

Runtastic

The Runtastic Pro application is a fitness and running app, which supports users in getting fit and healthy ("Runtastic Apps," 2015). The Android application is designed, based on the material design approach and illustrates activities in different views and visualization types. A list view gives the users an overview and illustrates the progress of physical activity. Different visualization techniques are used to show main facts about the workout, summarised in Figure 22. A list view combined with a horizontal bar chart shows the progress of each running lap. Line plots and a pie chart visualize the heart rate during the training session. Weather information and hard facts as textual elements are also part of the interface of Runtastic Pro. The statistical views are interactive and provide the possibility to combine different tracked parameters. The different parameters are overlapped and so illustrate the data over time. Detected data can also be analysed online via a platform which provides a more detailed view of tracked parameters. Figure 23 gives an example of the representation of the data. On the web platform, the athlete is given the possibility to add goals and create training schedules. Runtastic also provides sharing functions and real-time activity feeds to create a community. In addition to this, a map view is integrated into the online

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platform, where the user can see the route combined with lap times and heart rate measurements.



*Figure 22: Runtastic Android Application Statistical Views
("Runtastic Apps," 2015)*

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Figure 23: Runtastic Online Portal
 (“GOLD Mitgliedschaft | Runtastic - makes sports funtastic,” 2015)

Nike

Nike Fuelband is a tracking device, which detects different kinds of physical activities and turns everyday activities into “NikeFuel” (“Nike Fuelband,” 2015). The device is connected to the iOS or Android application via wireless connection and allows the user to see the progress on the mobile device. The concept of Nike Fuelband is based on fun and gamification. Training sessions can be shared and photos and personal minimum time can be communicated with friends in the sports feed or on different social media platforms. The smartphone application combined with the wearable device also provides real-time motivational messages and feedback. The goal setting process is based on daily targets the user sets. Different notifications to motivate and remember the user to be active are features of the application. As seen in Figure 24, the progress and amount of NikeFuel are visualized as bar charts and line plots. The colour range from green and yellow to red shows the amount of activity the user performs and informs about the level of activity during the day. Nike does not provide a web-based online platform to analyse and visualize the detected data. A pie charts illustrate

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the daily activity potential of the user, on the basis of a defined target. The main information is based on textual elements and numbers showing different amounts and hard facts.



Figure 24: Nike Fuelband Android and iOS Application (“Nike Fuelband,” 2015)

Adidas

Adidas provides different sorts of wearable devices focusing on different physical activities (“adidas miCoach,” 2015c). MiCoach SmartRun (“adidas miCoach,” 2015b), miCoach FitSmart (“adidas miCoach,” 2015a), miCoach Smart Ball (“adidas miCoach Smart Ball,” 2015) are available on the market and constitute a personal fitness coach. The wristband micoach SmartRun can track traveled distances, pace and calorie-burning, measure heart rate via heart rate monitoring devices and also give runners indications, for instance, of overexertion. The wristband coach picks up or brings down the pace via feedback systems like LED lights and vibrations. The workout data collected from the device can be transferred wirelessly to Adidas’s miCoach Train and Run applications for smartphones. The athletes can set up training programs within the app. The product adidas miCoach FitSmart detects the distance of running and stride frequency using an integrated accelerator pace. During training sessions, the colour strip of LED lights up to tell the athlete the intensity zone. A vibration alert gives the sportsman feedback during training sessions.

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The SmartRun and the FitSmart are closely connected to the adidas miCoach ecosystem, which is web-, desktop- and app-based. A combination of different graphs and textual information elements is shown on the online platform of miCoach. Different hard facts are illustrated in the form of texts and icon-based graphics, displayed in Figure 25 and 26. The performance visualization is a combined view based on a line plot and bar charts. Colours are used to indicate heart rate areas. A map view with highlighted routes and interactive features is also available. The core feature of the miCoach tool is the training schedule, which can be integrated into the calendar view of the online platform.

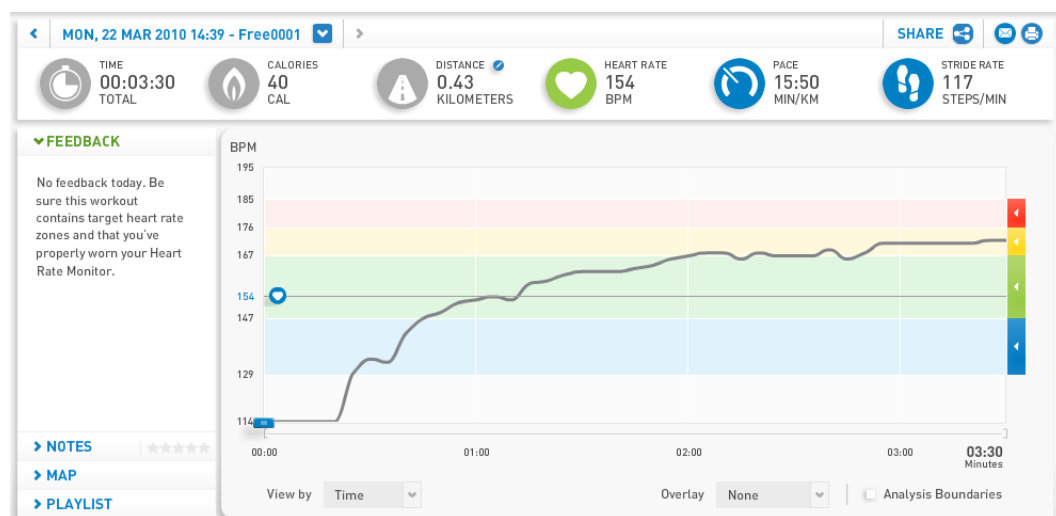


Figure 25: Adidas MiCoach Online Platform ("adidas miCoach," 2015c)

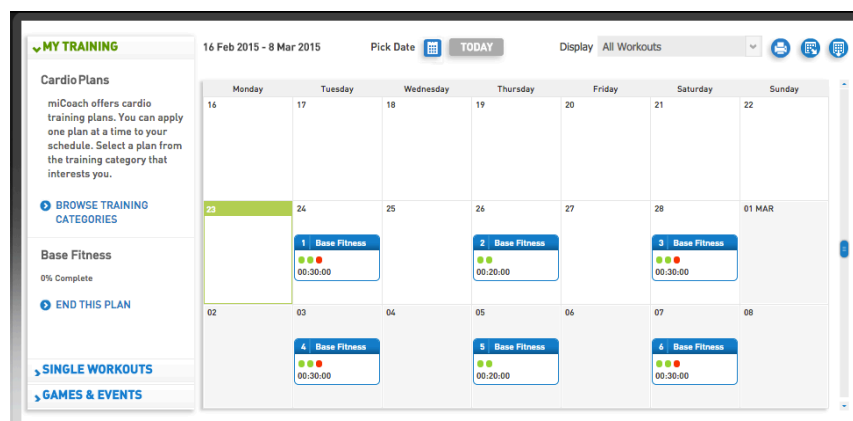


Figure 26: Adidas miCoach Online Platform Calendar View ("adidas miCoach," 2015c)

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The native applications are available for Android, iOS and Windows Phone and provide a different view and data analysis visualizations, summarised in Figure 27. Pie charts and bar charts are the main visualization techniques applied in the smartphone applications. Also charts, icons and textual elements are used to visualize the performance and parameters of the physical activity. Feedback and motivational messages are parts of the concept of adidas miCoach.

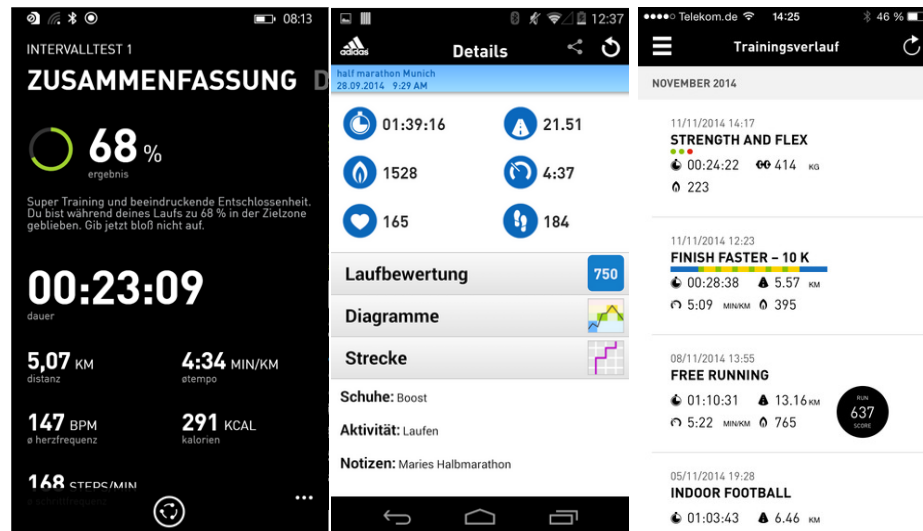


Figure 27: adidas MiCoach Windows Phone, Android and iOS
("miCoach Laufen & Training," 2015)

Fitbit

Fitbit offers various quantified-self devices which differentiate in terms of detected data and features. Most of them can track steps, distances, calories, length and quality of sleep and it is possible to see the collected data in real time on the smartphone application (*"Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker,"* 2015). The data is represented in the form of a customizable dashboard, both on the native application as well as on the web platform. As seen in Figure 28, the data is visualized in comparison with the user's defined goal. This form of comparison is defined as the value of the current status and the goal shown as a progress bar and as a percentage.



*Figure 28: Fitbit Application Windows & iOS Dashboard View
("Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker," 2015)*

There is also a web platform available where users can analyse their data. The dashboard design can be seen in Figure 29. The areas can be manipulated via drag and drop to personalize the dashboard view. A selection of different views of the dashboard is also a feature of the Fitbit data representation. By manually adding food or physical activities, the user gets the possibility to intervene in the automatic detection. The connection to other users of Fitbit and the share functionality are main parts of the self-reflection and motivation concept. The progress of gaining more physical activity units is visualized as a line plot. Different messages and notifications help the user to stay motivated and be informed about achieved goals.

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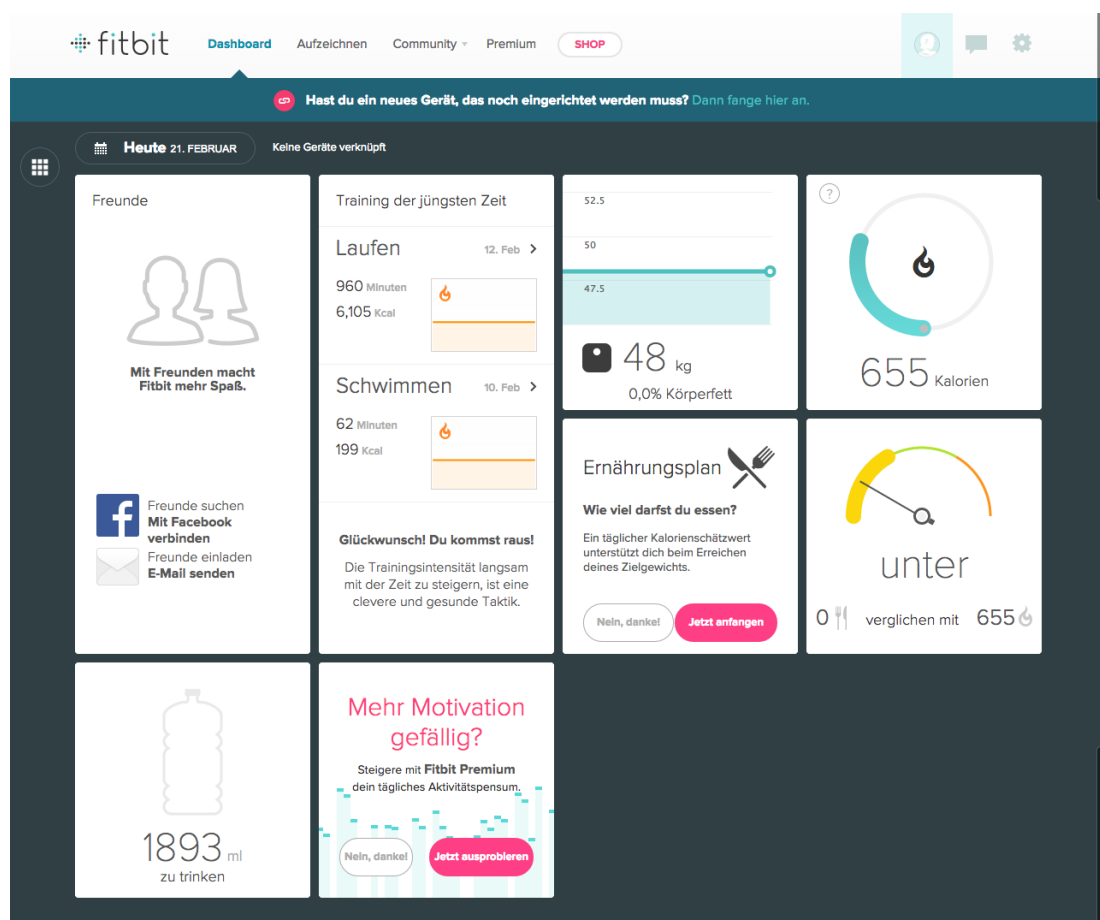


Figure 29: Fitbit Online Dashboard View
(“Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker,” 2015)

Garmin Connect

Garmin provides a web platform based on a dashboard design approach, presented in Figure 30. Android and iOS applications are also offered. The athletes can synchronize their data of different wearable devices or products by Garmin with the platform and analyse or plan activities via the online tool (“Garmin Connect,” 2015). A map, facts of physical activities in the form of textual elements, line plots and dot plots are integrated into the dashboard design. The user can combine different parameters to analyse the detected data. The goal-setting process is based on manual input areas and also provides an automatic detection of so-called “best training sessions”. The native application provides the same types of visualization techniques to illustrate the data to the athlete, seen in Figure 31. A list view of activities is also part of the smartphone application. Garmin also make use of the concept of social media interactions and community

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workouts. Different parameters and collected data are editable for users on the online platform.

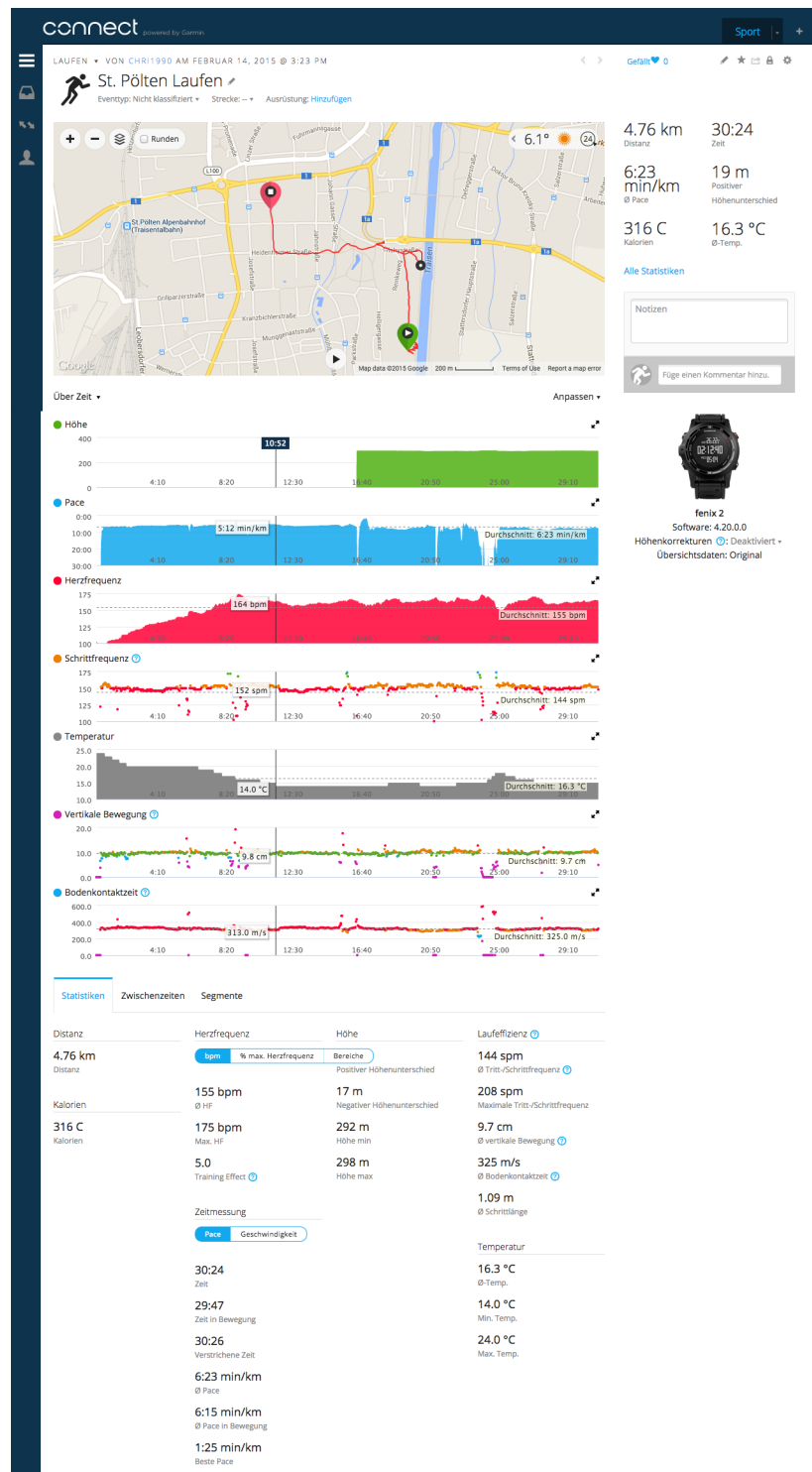


Figure 30: Garmin Connect Online Tool ("Garmin Connect," 2015)

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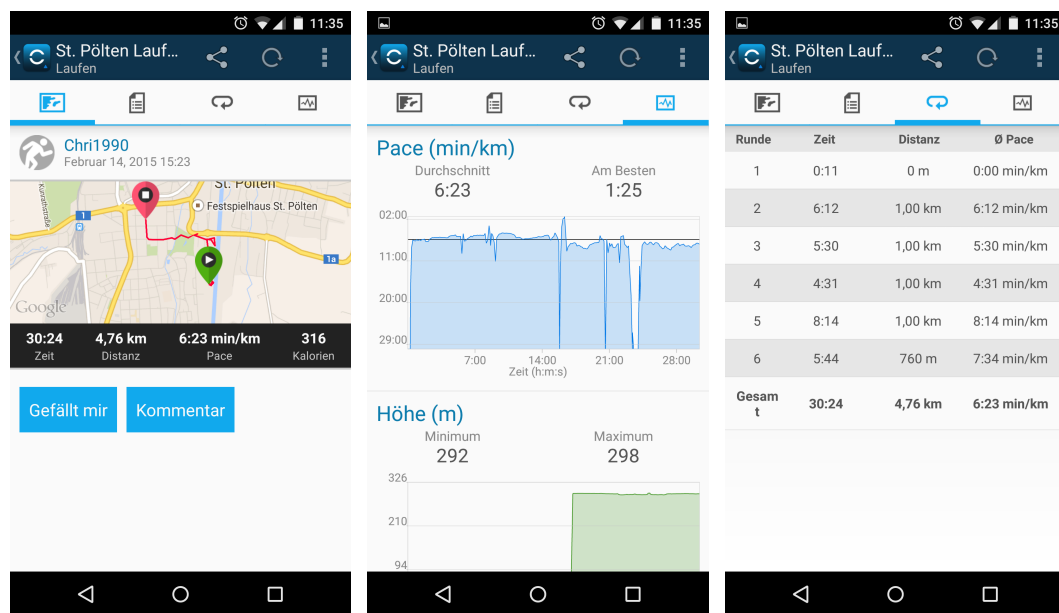


Figure 31: Garmin Connect Android Application
(“Garmin Connect™ Mobile – Android-Apps auf Google Play,” 2015)

Discussion

Figure 32 summarises the features and visualization techniques and illustrates differences between commercial products. It is apparent that various products implement bar charts and line charts to visualize the data. Five of the tracking devices use pie charts or a combination thereof. Comparing the results, it can be seen that six devices display trends in the form of line charts. List and calendar views are used four devies. All applications and representation on web platforms provide textual information. Six tracking devices provide interactive visualizations, five times via online tools and once in a native application. This application, called Moov Cardio Boxing, is based on an interactive sequence showing boxing movements which shall be imitated by the user. In bar or line charts, hover functions are used to illustrate special events and information. Garmin additionally provides select boxes and animation functions on the online platform. Related to the goal-setting process, manual inputs from the user and selecting training programs are the main features. Garmin Connect also provides a form of an automatically goal-setting or motivational approach by the presentation of „the best training session“ within the online tool.

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App Analysis of Commerical Products

Application or Online Tool	Line Chart	Pie Chart	Bar Chart	Map	Calendar View	List View	Notes
Endomondo App	X		X	X	X	X	
Runtastic App	X	X	X	X	X	X	
Fitbit		X	X				
Nike+ Fuelband	X	X	X				
adidas miCoach	X	X	X	X	X	X	
Moov Running & Walking			X	X			
Moov Swimming	X	X	X				Combination of Pie and Line Chart
Moov Cardio Boxing							
Moov 7 minute workout			X				
Garmin Connect	X			X	X	X	

Application or Online Tool	Interactive Visualization	Textual Information	Interactions	Layout	Goal-Setting	Platform
Endomondo App	Web Platform	X	Hover	Fixed	manually	web platform, native application (Android, iOS, Blackberry, Windows Phone)
Runtastic App	Web Platform	X	Hover	Fixed	manually	web platform, native application (iOS, Android, Windows Phone)
Fitbit	Web Platform	X	Hover	Adjustable	manually	web platform, native application (iOS, Windows Phone, Android)
Nike+ Fuelband	/	X	/	Fixed	manually - daily goals	native application (iOS, Android)
adidas miCoach	Web Platform	X	Hover	Fixed	manually	web platform, native application, desktop
Moov Running & Walking	/	X	/	Fixed	/	native applications (iOS, Android)
Moov Swimming	/	X	/	Fixed	select training program	native applications (iOS)
Moov Cardio Boxing	Native Application	X	/	Fixed	select training program	native applications (iOS)
Moov 7 minute workout	/	X	/	Fixed	/	native applications (iOS)
Garmin Connect	Web Platform	X	hover, select boxes, animation	Fixed	automatically, manually	webplatform, native application (iOS, Android)

/ ... not gathered

Figure 32: App Analysis Overview: The first table gives an overview of used visualization techniques in commercial products. The second illustration shows which platform is available, and gives information of the used interaction concepts and layout possibilities. The goal-setting process through the systems was also part of the analysis of commercial products. All products were investigated according to interactive visualizations. Tracking Book for Rock Climbing

3.6 Tracking Book for Rock Climbing

Several native applications for tracking climbing routes are available on the iOS App Store and Google Play Store. ClimbCoach (“ClimbCoach - Diary,” 2015) has been developed to make training for bouldering and climbing easier. Different videos and images explain the correct workout. ClimbCoach gives the users essential information needed to reach their goal quickly and safely. The diary functionality allows the users to plan their training day by day. The passed workouts are added automatically to the diary and give the users the possibility to keep the progress of climbing over time. The application allows the athletes to record the routes and boulders they have completed. A seven, 30 or 90 days period view of the tracked data is viewable on the native application.

Another coaching tool for bouldering provides coaching videos and voice-over features to get strong enough to hand bouldering terrain. Animated demonstrations with detailed descriptions and a function to track workouts and exercises are the key features of fitivity (“Bouldering Climbing Strength,” 2015). This app is one of the various applications from fitivity and is designed for the sport of bouldering.

Crags Climb Log book is available on Android and iOS platform and provides features like annotating routes and logging climbs for oneself or for a whole group of climbers (“Crags Climbing Log Book,” 2015). Figure 33 shows the annotate route function of the iOS platform.



*Figure 33: Crags Climb Log book iOS Application
("Crags Climbing Log Book," 2015)*

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A mobile climbing guide for the UK with over 4000 routes and photo-topographies is called E10Climbing (“E10Climbing,” 2015). The application provides a large database of routes consisting of different information like online and offline maps, route grade, approximate height, colour-coded grade ranges/routes for quick referencing between easy, medium and hard routes. Moreover, the possibility of full screen and zoom in, for planning the route before arriving at the crag, is available. The comments, tips and descriptions and experiences can be shared. The climbed route can be added to the logbook. The interface and photo-topography are displayed in Figure 34.

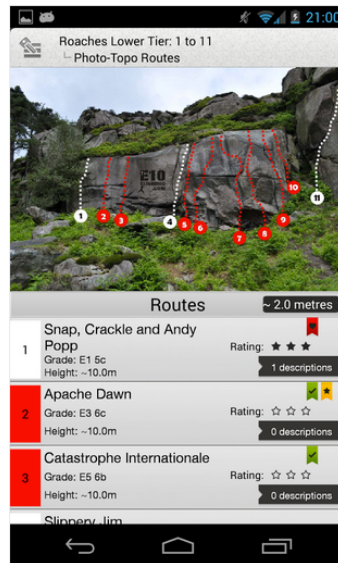
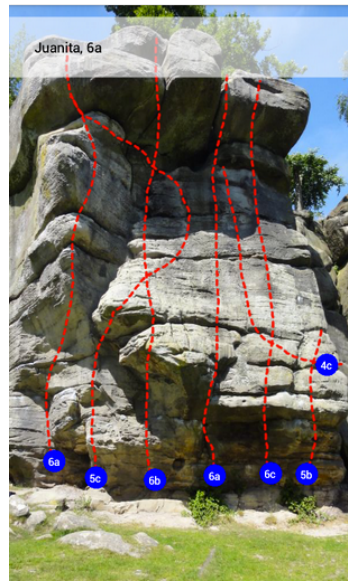


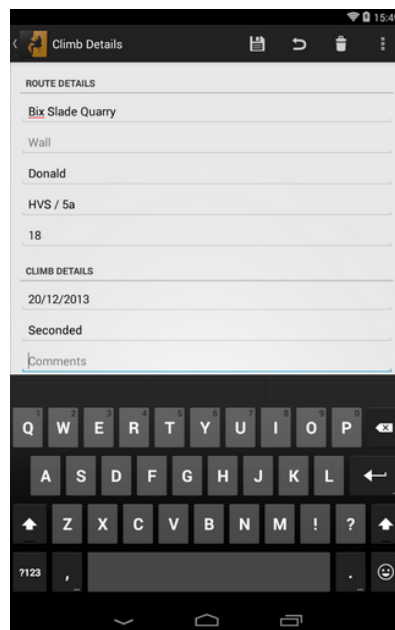
Figure 34: E10 Climbing Android Application (“E10Climbing,” 2015)

The application Craggie helps climbers plan and share their climbing activities (“Craggie - Your next adventure starts here,” 2015). The features of the application are divided into different parts. A central search by route name, country or town is implemented. The user gets essential information about each crag including location, access tips and an area map. A full-photo-topography with route names and grades are integrated in the application, displayed in Figure 35. The application allows the user to track the climbs by adding them to the logbook.



*Figure 35: Craggie Android Application
("Craggie - Your next adventure starts here," 2015)*

Simple Climbing Log offers a logbook for climbing on mobile devices by manually adding routes and tracks with different parameters: Route name, date and time you climbed, crag and wall names, grade, category, the length of climb, climbing partner and comments. The user can export the data into a spreadsheet ("Simple Climbing Log," 2015). Figure 36 shows the interface of Climbing Log.



*Figure 36: Simple Climbing Log - Android Application
("Simple Climbing Log," 2015)*

Beside the applications mentioned above there is some research done in the field of a digital diary named Affective Diary, in which users can scribble their notes and combine them with recorded sensor data collected via mobile phones. Ståhl et al. (2009) presented an investigation in three lines of inquiry: a theoretical grounding for affect and bodily experiences; a user-centered design process; and an exploratory end-user study with the developed system. The system consists of a mobile phone, body sensors and a tablet PC. The user tracks activities during a day via a mobile phone and a body sensor and then connects it to a tablet PC. As seen in Figure 37, the sensor data is presented as shaped and coloured figures mapped along a timeline. The user can interact with these figures and create a story.



*Figure 37: Final Concept of Affective Diary System
(Ståhl et al., 2009)*

Other kinds of logbooks or diaries are used in the field of medicine, especially in chronic illness management (MacLeod, Tang, & Carpendale, 2013) and chronic pain illnesses. People with chronic pain fill out “pain-diaries” via smartphone-based applications and also get the possibility to track more information with other digital sensors (Ballegaard, Hansen, & Kyng, 2008) to better understand their conditions (MacLeod et al., 2013). In the field of logbooks or diaries for collecting and logging physical activity no research has been conducted. Only some commercial products are available for climbers as mentioned above.

In summary, these applications offer features to explore and analyse existing routes. The applications illustrate facts of routes and walls, derived from an existing database. Comparing the discussed applications, a lack of a system combining the functionalities of a logbook and an analysis tool can be identified.

Discussion

The literature review showed the importance of providing a system for climbers, especially a self-assessment tool. To date, several studies have begun to examine the use of quantified-self systems to track daily routines, human behaviour and physical activity. Different research publications have been found which cover different aspects of this topic such as evaluation of quantified-self applications (Klasnja et al., 2011), how to motivate users and how these systems should be designed to support users in changing their behavior (Consolvo, Libby, et al., 2008; Tudor-Locke, 2002). Also different commercial products like Fitbit, Jawbone UP, misfit Shine Runtastic, Endomondo, FitBit, Garmin could be identified for sports such as running, cycling or strength training. These applications can be used in combination with wearable devices. The data collected by the integrated sensors of the smartphone or wearable devices are illustrated in the form of different visualization techniques (bar charts, line plots, calendar view, pie charts and maps). Various applications also use lists to display performance data of an athlete. None of these systems offer features or tools for climbers.

Also research was done in terms of using wearable devices for tracking physical activities in training sessions. Some studies have demonstrated how to design applications which provide information about technical skills and quality of movement ("Meet Moov," 2015; "adidas miCoach," 2015c; Hogenboom, 2014) of a physical activity such as golf swings (Grober, 2010) and swimming (Bächlin et al., 2009). The long-term use of wearable devices detecting physical activities were analysed by Fritz et al. (2014). Different commercial products are available on the market which support athletes increasing their performance. Native applications and analysis tools such as web platforms were part of the literature review. In this field different visualization techniques could be identified. Spiral, Rings, Buckets, Pollock or Spiral Timelines are visualization techniques (Fan et al., 2012), which are used in quantified-self applications on mobile or desktop devices. The visualizations and results of these studies examined the use of wearable devices independent of sports. Guidelines and heuristics developed and identified in different studies (Cuttone et al., 2014; Consolvo, McDonald, et al., 2009) provide an insight into the way people use wearable devices and quantified-self systems. But little is known about requirements of especially climbers in particular or athletes of different other sports and it is not clear what the requirements for quantified-self applications for the specific domain of climbers are.

During the problem analysis, contextual interviews were conducted to identify climbers requirements for a self-assessment system. Interviewees mentioned the need of a logbook or diary and tracking special climbing routes (R6). Up to now, a number of applications in terms of logbooks for climbers have been identified. Most of the available systems offer features to explore and analyze existing routes. Logbooks or diaries in other fields can be identified in medicine.

Considering all these points, it seems that there is a lack of systems for climbers combining the functionalities of a logbook or diary and analysis tool.

In the next chapter a concept will be presented which considers the identified requirements for climbers and also results and design guidelines of the literature review of existing research work.

4 Concept

In this the design concept of the web-based mobile application and interactive visual presentation and analysis tool is described. Moreover, the results of the expert reviews are documented.

4.1 Method

Based on the results of the semi-structured contextual interviews and the analysis of different native and web applications, a concept has been developed. The first step was to create hand-drawn sketches to gather ideas for the user interface design and visualizations. Sketch ("Bohemian Coding - Sketch 3," 2015) a graphic program, was applied to convert drawings into high-fidelity wireframes. The feedback and results of the semi-structured interview and expert review were included in the concept and described in chapter 4.6. A scenario-based prototype based on HTML, CSS, JavaScript and D3.js was implemented and tested.

4.2 Mobile Web Application

Munzner defines a *what-why-how* framework to describe and analyse visualization use (Munzner, 2015, pp. 43-64). The question of *what* comprises the visualizations was answered in chapter 2.2, giving insights into the data and the categorization of it.

The *why* part of the framework describes why people are using visualizations and why a task is performed (Brehmer & Munzner, 2013). Identified by Munzner, the highest-level action is to use visualizations to *consume* or *produce* information (Munzner, 2015, p. 43). Furthermore, this idea of consuming information was chosen because of the identified needs related to the contextual interviews giving an overview of the training data on the mobile device (R2). Climber beginners are able to discover the data and advanced users, knowing the tool, use the output of the discover session for the present session.

The mobile web application expresses a logbook and mobile analysis tool. The automatically collected data of the wrist-worn device formed the basis for the application. Besides, the need for recording and adding different information was addressed in the form of manual input possibilities via the mobile web application interface (R6). In contrast to the visualizations for analyzing data, the manual input feature allows users to produce new material. Using the language of Munzner's framework the *why* part can be defined as a produce goal of *annotation* (Munzner, 2015, p. 49). The manually collected data was integrated into the collected data of the sensing devices.

In order to meet the need of climbers of getting tips and motivational messages to gain feedback (R7), in-application feedback was integrated in the form of textual feedback messages (Consolvo, 2012, p. 238ff). These messages notify users of substantial changes in their training activities and also call attention to changing parameters and performance data.

The given data structure, logged parameters with the sensor device, and the requests of climbers were the basis for creating the concept. The need for showing the number of climbs, the time in the route, the time between routes, the grade as well as giving insight about the resting time and number of moves was identified (R3 and R4). The system should also present information like data, comments and a documentation of the daily conditions (R6).

4.2.1 Layout

The application provides different parts and visualization types to show data to the target group. Time-oriented multivariate data and manual input data of the user via the application were the basis for the conception. Research in Information Visualization related to quantified-self applications has resulted in a body of guidelines (e.g. (Cuttone et al., 2014; Consolvo, McDonald, et al., 2009)). Various visualization techniques, discussed in chapter 3, do not encode all types of time-oriented and manually added data for the exploration of quantified-self sensor data. Thus, a collection of well-established visualization techniques and methods identified in the course of the contextual interviews was utilized. The designed interface enables the user to consume the given data and simultaneously use the mobile interface for adding additional information to climbs. The question of *how* visualizations can be constructed is also part of the *what-why-how* framework of Munzner (2015, p. 57f). The mobile web application is structured in the form of a vertical list based on the common *card layout pattern* (Information is assembled in the form of a card.) (Cooper, Reimann, & Noessel, 2014, p. 526). Munzner (2015, p. 57f) distinguished between classes of

methods: encode, manipulate, facet and reduce. This way, the method of manipulating in the form of *navigating* was defined.

Figure 38 shows the user interface of the mobile web application.

- The design of the header combines a section for photographs or uploaded pictures and information such as date and location information (cf. Figure 38, area 1).
- A defined score of today's climbing in comparison to the worst and best grade of the last training days is illustrated in the form of a donut chart. Hard facts are situated in the middle of the chart to give the climber a short overview of the collected data of the sensors. Figure 38, area 2 illustrates the visualization technique.
- Different messages based on the results of the climb act as motivational messages and a textual abstract of today's climbing performance, illustrated in Figure 38, area 3.
- As shown in Figure 38, area 4, the navigation concept is based on the mobile navigation pattern *page swiping* identified by Neil (2014, p. 48ff) combined with small arrows for navigating through the days of climbing without using swipe gestures. The card view is updated based on the selected date.

The *card layout pattern* (Cooper et al., 2014, p. 526), described above is selected for layout and provides three cards that are separated as follows:

- The first card contains different input possibilities, in the form a drop down field for adding a category of climbing, input buttons for adding a climbing partner and selections based on icon buttons to add daily conditions (cf. Figure 38, area 5).
- Figure 38, area 6, illustrates an overview of the routes and provides the possibility to expand the card to get details to climbed routes on demand.
- An overview of the balance between right and left hand is illustrated in the last section, presented in Figure 38, area 7. The user can expand the card and get more information related to the balance of the left and right hand.

The concept of expanding cards to get more information can be explained as the idiom defined by Shneiderman's mantra of *Overview First, Zoom and Filter, Details on Demand*. This concept emphasises the interplay between the need for giving the user an overview and seeing details (Shneiderman, 1996). Using the language of the *what-why-how* framework of Munzner (2015, p. 55), it is an idiom

with the goal of *summarising*. The overview gives the user the possibility to a broad awareness of the entire information space. The overview of the routes at the beginning of the *exploration* process guides users in choosing where to drill down to inspect the information in more detail via the mobile application and shows them information is worth being analysed within the analysis and presentation tool. The users get insights into their data, by scrolling through the application. By expanding the card view, the users can instantly analyse the climbing data in detail. Munzner (2015, p. 55) shows four kinds of abstract targets. The high-level targets *Trends*, *Outliers* and *Features* are relevant for all kinds of data. This way, in the mobile web application user can find trends and outliers in their performance data.

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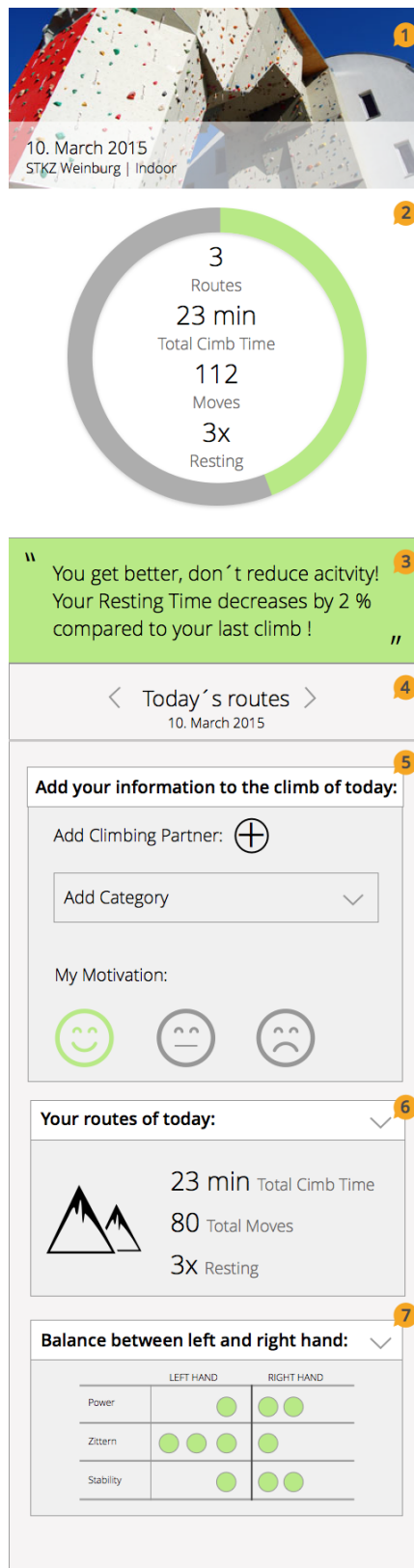


Figure 38: Concept View of Mobile Web Application

4.2.2 Visualization Techniques & Interaction Design

The interface offers three simple, but intuitive visualization techniques.

- A stacked bar chart for quantitative information
- A table combined with graphical elements with the character of showing amounts of data in horizontal lines
- A donut chart for illustrating the daily score of climbing

The donut chart shows the score of the climbing related to the actual training day (R9). The user gets an overall impression of the training level by analysing the donut chart. This visualization can be characterised as well-known, based on the contextual interview results. Figure 39 shows the visualization techniques in detail.

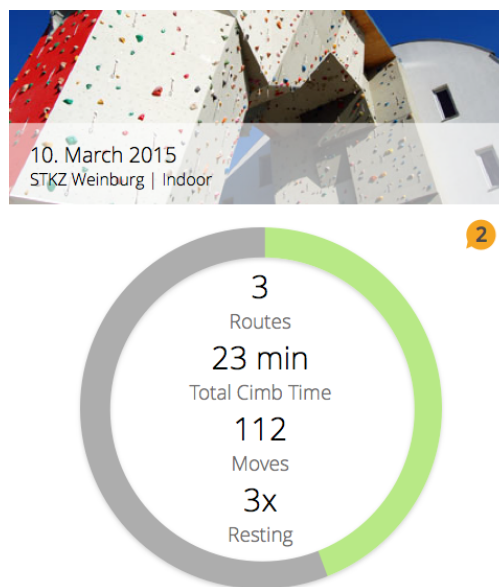


Figure 39: Pie Chart Visualization showing the training score

Identified in the course of the contextual interviews, the *pie chart* is familiar and users can interpret it without training. Cuttone et al. (2014) identified four design heuristics for creating interactive visualizations of self-tracking data. The first heuristic “Make Data Interpretable at a Glance” is the main principle followed in the design process of the concept. All visualization techniques and views are designed to provide quick and efficient interpretation (R1). This way the design requirement identified in the interviews can be met.

The bar chart can be used to compare different values (R9). The number of bars represents the number of climbed routes in one particular session. The height of

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the bars encodes the total time climbing of the routes. The stacked element gives the user the insight into total resting times in relation to the amount of time on the route. Textual elements and the possibility to add grades and comments to a particular climbing route is also part of the visualization to meet the requirements of climbers. As gathered in the interview climbers should get the possibility to manually add comments to routes (R6). The user gets detailed facts such as time, total climb time, total resting time and the number of moves by manipulating the slider. Added comments to a route are situated above the bar chart, which can be seen in Figure 40.

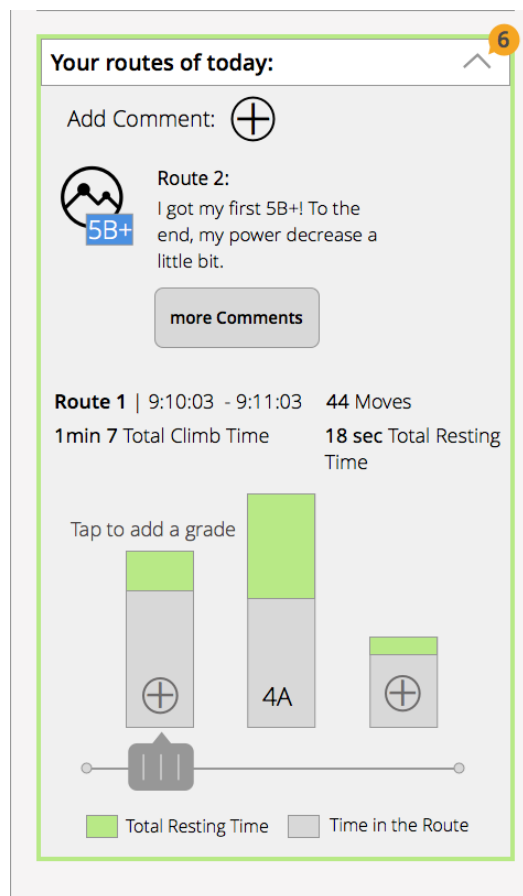


Figure 40: Route View Mobile Web Application

The third view gives insights into the ratio between the parameters power, control and stability identified by Ladha et al. (2013). The parameters are measured for the left and right hand, based on the fact of wearing two wristbands. As shown in Figure 41, the visualization combines this data by using a table with two columns, one for the left and one for the right hand, and three lines mapping the three outlined parameters. Circles show the characteristics of the parameters.

Messages, which advise users of disbalances, are integrated into the design. A description of the illustrated parameters power, smoothness and stability is also part of this section.

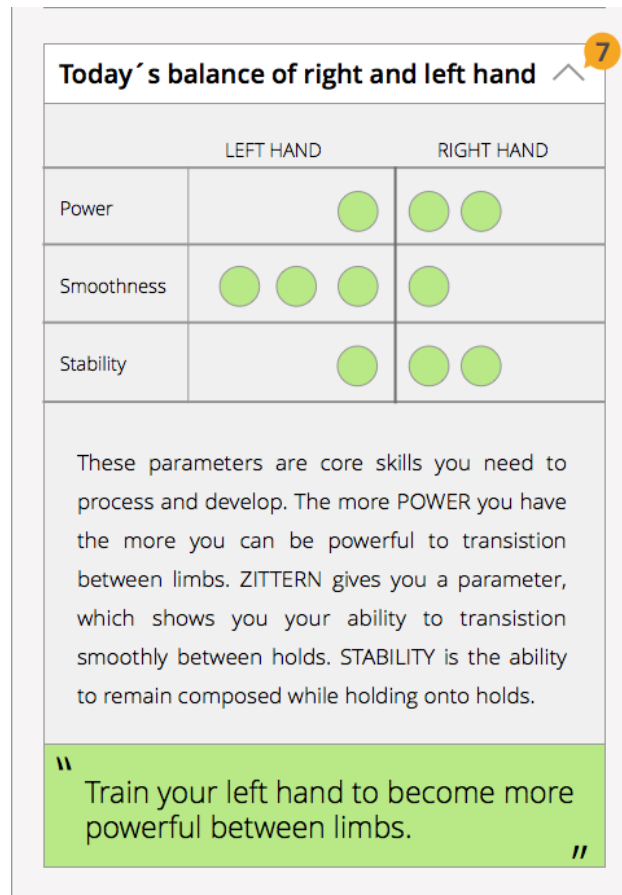


Figure 41: Balance View Mobile Web Application

4.3 Interactive Visual Presentation and Analysis Tool

To cover the identified design requirements, the web application, optimised for desktop devices, provides different visualization techniques and data to give climbers the possibility of exploring and analysing data in more detail.

The *what-why-how* framework developed by Munzner (2015, p. 47ff) defines the task of analysing data to consume existing information or produce new information as the highest level of framework. The goal is to find new knowledge and investigate existing theories, models or hypotheses by *discovering* the

visualizations. The web application is a tool to analyse data in more detail and thus react to changes in the climbing training. The web interface takes up the visualization techniques used in the mobile web application such as stacked bar charts, the donut chart and the illustration showing the balance between left and right hand. Various other visualizations by combining different data to provide more detailed information are embedded in the web interface.

The visualization techniques are selected on the basis of the known visualization techniques identified in the course of the contextual interview. Thus, the tool offers a line plot combined with a bar chart to provide the possibility to analyse climbing data over an extended period. The line plot can be used to spot and compare trends and patterns. A horizontally grouped bar chart sets out the progress of the three parameters power, stability and smoothness over the climbed routes on one climbing day.

Single static views can present only one aspect of a dataset (Munzner, 2015, p. 9). Thus, the presentation tool provides interaction possibilities so that users can *explore* large data spaces and find patterns in their personal climbing training. Interaction is regarded as “at the heart” of Information Visualization (Spence, 2007). Climbers can *filter*, or *navigate* through the visualizations over time. Therefore, the amount of data depicted in one view can be reduced by these implemented interaction techniques and so cut visual complexity (Munzner, 2015, p. 301).

4.3.1 Layout

The web interface is separated into two different areas and provides visualizations to get insights into the daily climbing conditions and the parts to analyse data over a longer period of time. Figure 42 illustrates the interface design of the presentation and analysis tool.

- The first section illustrates today’s climbing score in the form of a donut chart, the textual message, as well as a comment section, added through the mobile web application and illustrated here in the web interface. The used methods are equal to the mobile application (cf. Figure 42, area 1).
- Adjacent to this area, the manually added data from the mobile application are displayed, illustrated in Figure 42, area 2. The taken picture or header photography is also part of this segment.
- As shown in Figure 42, area 3 and 4, a bar chart illustrating routes and a table view showing balances between the right and left hand are the next sections of the interface.

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- The last view of the section of today's climbing information is a grouped bar chart that shows the balances between right and left hand classified according to the routes (cf. Figure 42, area 5).
- The combined line plot and bar chart in combination with hard facts constitute the overview visualization (cf. Figure 42, area 6).

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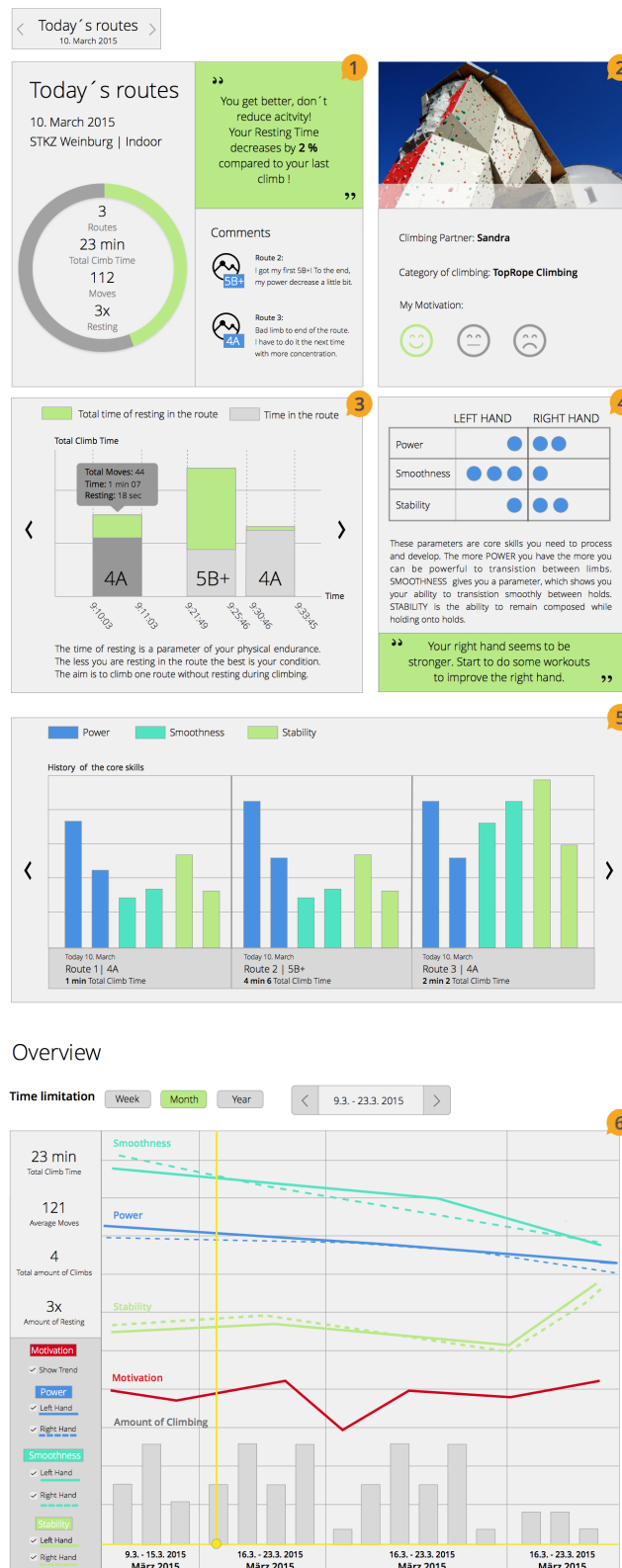


Figure 42: Web Application Interface Design

4.3.2 Visualization Techniques & Interaction Design

The design requirement for combining the number of climbs, the time in the route, the time between climbs as well as the grade of routes to gain the possibility of analysing physical condition improvements can be met by integrating this information in the form of a stacked bar chart (R4). The bar chart is also part of the mobile application. The x-axis represents the time and the y-axis the duration of the routes. Clicking a bar, a *tooltip* appears, which illustrates data such as total moves, time in route and the resting time. A carousel pattern ("Carousel Pattern - Design Pattern Library - YDN," 2009) is implemented to be able to navigate horizontally through the routes over time with arrow buttons at both ends of the stripe.

As identified in the contextual interview, climbers strive for a balance between the left and right hand related to the power, stability and smoothness of their moves (R8). Thus, the interface provides two different visualizations to illustrate this information to climbers. As represented in Figure 42, area 4, the table view implemented in the mobile application is also part of the web tool. Referring to the framework of Munzner (2015, p. 47), the goal of *discovering* to acquire new knowledge can be identified as the user's dominant goal. Because of different levels of knowledge among climbers in terms of physical characteristics of the sport of climbing they can observe the data and so find disbalances.

The next visualization gives more detailed information about the trend (cf. Munzners framework of *why*) of the parameters power, stability and smoothness related to the climbed routes. The height of the bar represents the characteristics of the shown parameters. The bars are grouped according to routes and parameters. The pattern of a carousel view ("Carousel Pattern - Design Pattern Library - YDN," 2009) is used for navigation. This visualization gives a trend overview based on all climbed routes and a detailed view of the progress of the parameters related to one specific route.

This design requirement for analysing training data over a long period can be met by the combined view of a line plot and bar chart (R5). The parameters power, smoothness and stability are displayed in the form of a line. The motivation, which is derived from the mobile application, is illustrated in the overview visualization. The bar charts represent the amount of climbing over time. By hovering over the visualization, the user gets information about the climbing day. A filtering possibility is given to the user related to the parameters in the form of check boxes. The user can display or hide the trend line of each hand and parameter. Changing the view over time by selecting a year, month or week view is also part of the interaction concept.

“Once a target or a set of targets has been found, a user will identify, compare or summarize theses targets.” (Brehmer & Munzner, 2013, p. 2379) The used visualization techniques in the web application provide users the possibility to *identify*, *compare* and *summarise* various aspects of the data. The user can *identify* the results of a one climbing session, *compare* the information to other climbing sessions and *summarise* the whole performance data across a timespan of a year.

Figure 43 gives an overview of the used methods based on the *what-why-how* framework of Munzner (Munzner, 2015, pp. 43-64).

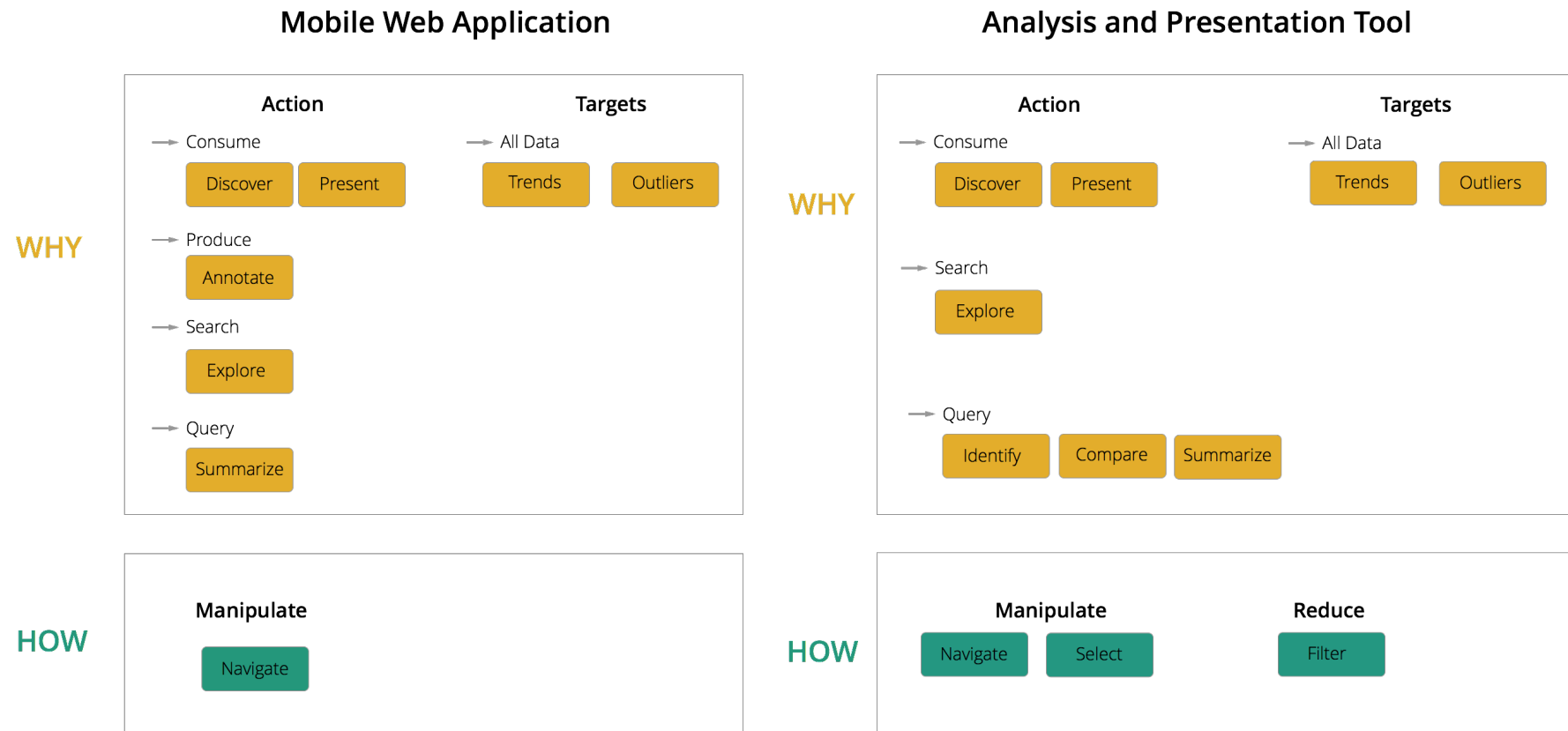


Figure 43: Overview of Used Methods of What-Why-How Framework

4.4 Interface Design

The design is based on the flat design approach (“Flat And Thin Are In,” 2015). The colour scheme is limited to a green, which is used for highlighting. Blue, turquoise and green are defined for the parameters power, smoothness and stability. Yellow is used for the hovering function in the overview visualization. Grey graduations are applied to background areas of the interface. Black is the main colour for textual elements. Figure 44 displayed the used colours in the interface.



Figure 44: Color Scheme Mobile and Web Application

4.5 Expert Review

In this section, the concept based on high-fidelity wireframes was tested with experts of different domains. The method, procedure and results are described in detail.

4.5.1 Method

In order to gain insights into the needs and requirements of climbers, expert reviews were conducted. This qualitative method offers an effective way of obtaining early feedback in the design process (Lazar et al., 2010, p. 256ff). Expert users also attempt to uncover obvious interface flaws, confusing wording and inconsistent layouts. A mobile web application and a desktop-based analysis and presentation tool formed the basis for this review. During the observation, handwritten notes and audio records were taken. Based on these improvements, the concept was adapted. The interview guideline can be seen in Appendix B.

To cover domain expertise of human-computer interaction, visualization and climbing, three experts were selected. The expert reviews were held in the form of an interview. The answers were documented via audio records and written notes. Firstly, the inspection of the mobile web application was initiated. Different paper prototypes in the form of high-fidelity wireframes were the basis. To show

interactions and navigation actions, different screens were utilized. The experts analysed the wireframes based on the scenario and the defined metrics.

Explaining the aim of the review and introducing the subject of the thesis was the first part of the interview. Secondly, two scenarios were introduced, which provided the basis for the structural inspection of the wireframes. Predefined metrics constituted the basis for the review. On the one hand, these metrics were used to classify the answers and, on the other hand, to give the participants a structure. The following metrics were defined and presented in the list below:

- Consistency of elements
- Used visualization techniques
- Wording
- Colour
- Used Interaction Techniques
- Navigation Concept
- Layout
- Simplicity

Key path scenarios, identified by Alan Cooper, were developed to gain an insight into the idea and concept of application wireframes and describe the user interaction with the application (Cooper et al., 2014). Two different scenarios were used respectively for the mobile and desktop application.

- **Scenario 1 for mobile application inspection:** After climbing with your friend Mike, you have to wait in the changing cubicle. During this time, you analyse the climbing day by using the mobile application on your smartphone. Since the launch of the wearable devices by ClimbAX, you have been using those for documenting your climbing. You are opening the mobile browser and analysing the data. You are interested in different routes, your status of improvement and also in the balance between the left and the right hand. You also add grades to the routes. Because of your achieved goal - getting a 5B+ route – you add a comment.
- **Scenario 2 for desktop analysis and presentation tool:** During your analysis you identify the disbalance between your right and left hand and decide to look through the data at home. You are interested in the history of the parameters power, smoothness and stability. Because of doing exercises to improve the power of the right hand and the attempt to compensate the disbalance, these parameters are important to you.

4.5.2 Experts

Expert	Domain	Gender	Profession
E1	Interface Design & Visualization Expert in quantified self applications	male	Senior Research Associate at Newcastle University
E2	Expert in Rock Climbing, certified climbing instructor, climbing for 10 years	male	Laboratory technician at Constantia
E3	Mobile Interface Design Expert	female	Researcher at University of Applied Sciences St. Poelten

Table 2: Experts Participating in the Expert Review

4.5.3 Results

A number of issues were identified based on the metrics defined for the expert review. The experts gave feedback on the following aspects: consistency of elements, used visualization techniques, wording, colour, used interaction techniques navigation concept and layout. The results were described in the order of the parts of the interface design.

Mobile Web Application:

The consistency of elements was evaluated as given in the mobile web application.

Related to the used colour green two experts argued its inconsistency.

“The colour will be classed as something ‘good’ and ‘positive’. So it is difficult to use the colour also for highlighting things. The colour palette should contain a primary colour and nuances in terms of different saturation values.” (E1)

When the participants were asked to analyse the visualization of the today’s climbing status on the mobile application, the majority commented that the type of visualization was unsuitable for showing a climbing status compared to other climbing days. The donut chart shown in Figure 36 was interpreted as the time of climbing compared to the last training day.

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The used visualization techniques on the mobile web application were estimated as easy to understand and familiar by the target group. Also, the interaction concept was seen as easy to use. To give the users the possibility to analyse their routes, a bar chart was implemented, illustrated in Figure 45 (the visualization on the left). During the interview, another chart was given to the expert, representing the route overview in the form of timeline visualization, which can be seen in Figure 45 on the right screenshot. Expert 3 puts it as follows:

“The two types of visualization give the user an overview of their routes, but the timeline visualization intensifies the time of the routes climbed by the athletes. It depends on the needs of the target group which kinds of techniques should be implemented in the system.” (E3)

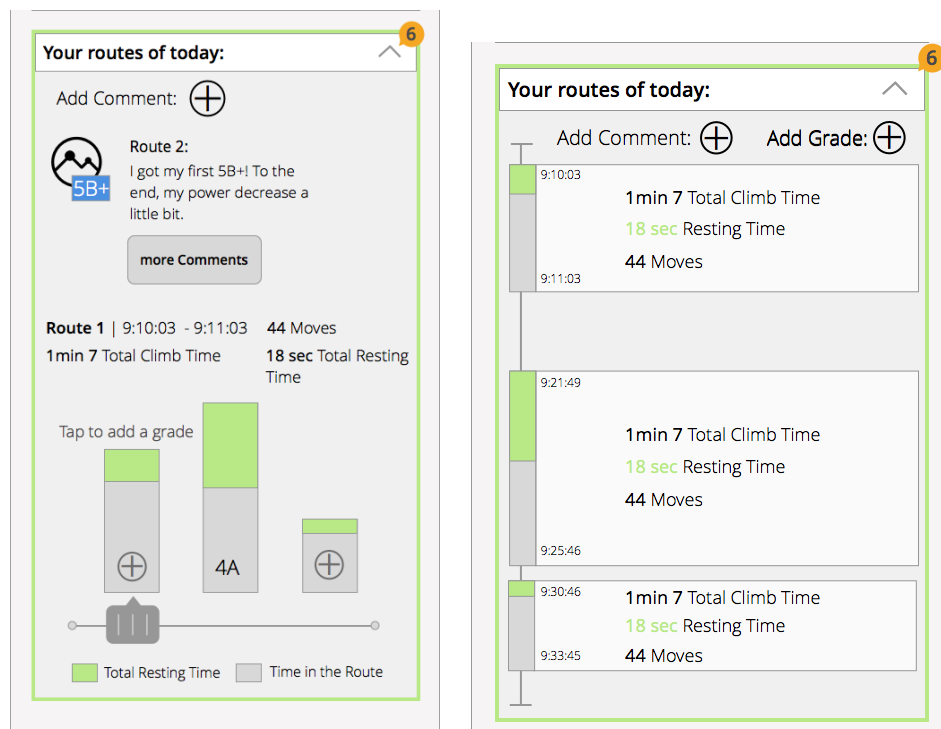


Figure 45: Route View Version 1 (on the left) & Version 2 (on the right)

The interaction concept of using a slider to navigate through the bars and get information on demand was identified as too complex by Expert 3.

The concluding part of the mobile application gives the users an overview of their balance of right and left hand based on the parameters power, smoothness and

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stability. The wording of the parameter Control, defined by the researchers of ClimbAX, came up in discussions. Expert 2 defined the word smoothness as suitable. Expert 2 also made some other wording suggestions:

“Limbs are not common in the climbing domain, use holds instead. This way every climber knows what you mean.” (E2)

The idea of giving the user automatically generated messages of the system to provide a virtual training guide was discussed because of the design and reasonable usage of such motivational messages. Expert 1 and 2 argued that the design and communication of such motivational feedback systems had to be very intelligent to be motivational for athletes.

“If you have a bad day and you know that you don’t perform well, and the system tells you that again, it could be very demotivating for the athletes.” (E1)

Expert 3 categorised the idea of giving tips and motivational messages as important, especially for beginners.

The used visualization technique for showing disbalances was commented as very suitable. Expert 3 pointed out the chronology of the elements in this area.

“Put the message below the visualization to give the message more importance. The description of the parameters is necessary the first time the application is used.” (E3)

Representation & Analysis Tool adopted for Desktop Devices:

The feedback mentioned above can be also applied to the web application. Color inconsistencies were also commented by evaluating the desktop version.

Expert 1 and 3 reported that there were too few interaction possibilities for the user on the web application. Expert 1 gave the hint to use tab bar navigation elements to give the user the chance to explore the information and get new insights into the training data.

The visualization number 5, illustrated in Figure 42, could be improved by adding filter possibilities to limit the displayed information. Expert 3 indicated that the design and coloration of the bars in the bar chart is confusing. The difference between left and right hand is insufficient. Furthermore, Expert 2 suggested a missing y-axis description.

The interaction techniques of filtering elements and limitation of time were commented as positive in the overview visualization, shown in Figure 42, area 6. Expert 2 also referred to the missing y-axis description. Expert 1 and 3 evaluated

the integrated bar chart as difficult to measure because the height and number of bars are not interpretable at a glance.

Discussion:

Summarising all feedback points on the basis of the metrics defined in the interview, the following areas need to be improved:

- Wording improvements in the mobile and web application
- Colour usage related to the consistency and mapping
- Interaction techniques are used too little in the interface of the web application
- Usage of visualization techniques for illustrating climbing scores and the the view of the balance between left and right hand over route progression (cf. Figure 42, area 1 and 5)

4.6 Concept Revision

Based on the feedback given by the experts a second iteration was conducted to improve the design of the mobile and web application. Inspired by the experts feedback, some additional design and concept issues were improved. The following listing represents the amendments of the user interface:

Mobile Web Application

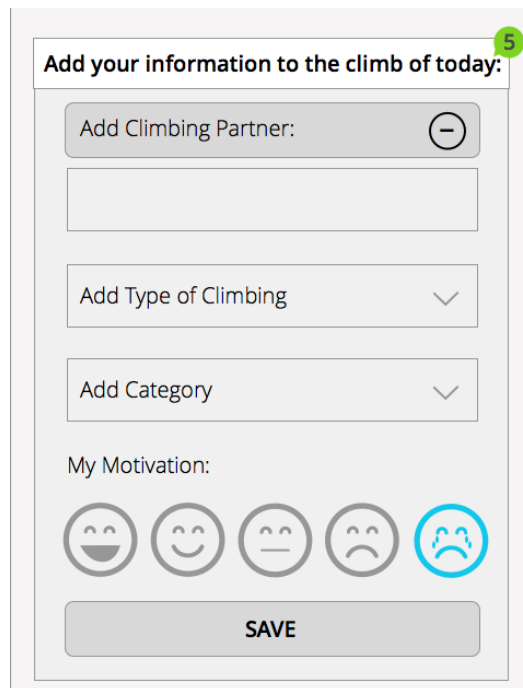
- The primary colour blue is used to highlight elements and is the dominant colour in the interface. Three different colours are used to outline the parameters power, smoothness and stability. Grey gradutions are defined for the bars in the bar chart and background colour. Text elements are displayed in the colour black. Figure 46 shows the colours and their weighting.



Figure 46: Color Scheme

This colour scheme is defined for the mobile web application and the analysis tool for desktop devices.

- Figure 48, area 2, represents the climbing score of today's climbing session visualized based on a bar, where the user can compare the current session to the worst and the best score of climbing training. The donut chart, presented in Figure 39 area 2, was replaced.
- Climbing partner, type of climbing, category and motivation can be added to the mobile interface. Input fields, drop down lists, and icon buttons are the used *form pattern* (van Welie, Martijn, 2015). Figure 47 gives an overview of the interface.
- A summary of the different facts, matching the collected data of the sensor, such as total climb time, moves, number of resting are displayed in the second card. These facts reinforce their significance in the form of icons. By tapping on a bar, the user gets detailed facts about the climb such as time of climbing the route, total climb time, total resting time and the number of moves. The manually added grade is shown in this visualization. The x- axis is labelled with „routes“. Added comments to a route are situated above the bar chart. Figure 48 gives an insight into the design of this visualization.
- Critical parameters related to a disbalance between left and right hand are highlighted in the form of traffic light colours, displayed in Figure 48 area 7. Red signals a disbalance and the green colour balance between the right and the left hand. A message is integrated to call attention to disbalances. The description of the parameters is positioned above the message.



A mobile web application input area for adding climbing information. The form is titled "Add your information to the climb of today:" with a green circle containing the number "5" in the top right corner. The form contains the following elements:

- A label "Add Climbing Partner:" followed by a minus sign icon in a circle.
- A text input field.
- A label "Add Type of Climbing" followed by a downward arrow icon.
- A label "Add Category" followed by a downward arrow icon.
- A label "My Motivation:" followed by five circular icons representing different levels of motivation: a wide smile, a slight smile, a neutral face, a sad face, and a crying face. The crying face icon is highlighted with a blue border.
- A "SAVE" button at the bottom.

Figure 47: Concept Revision: Mobile Web Application Input Area

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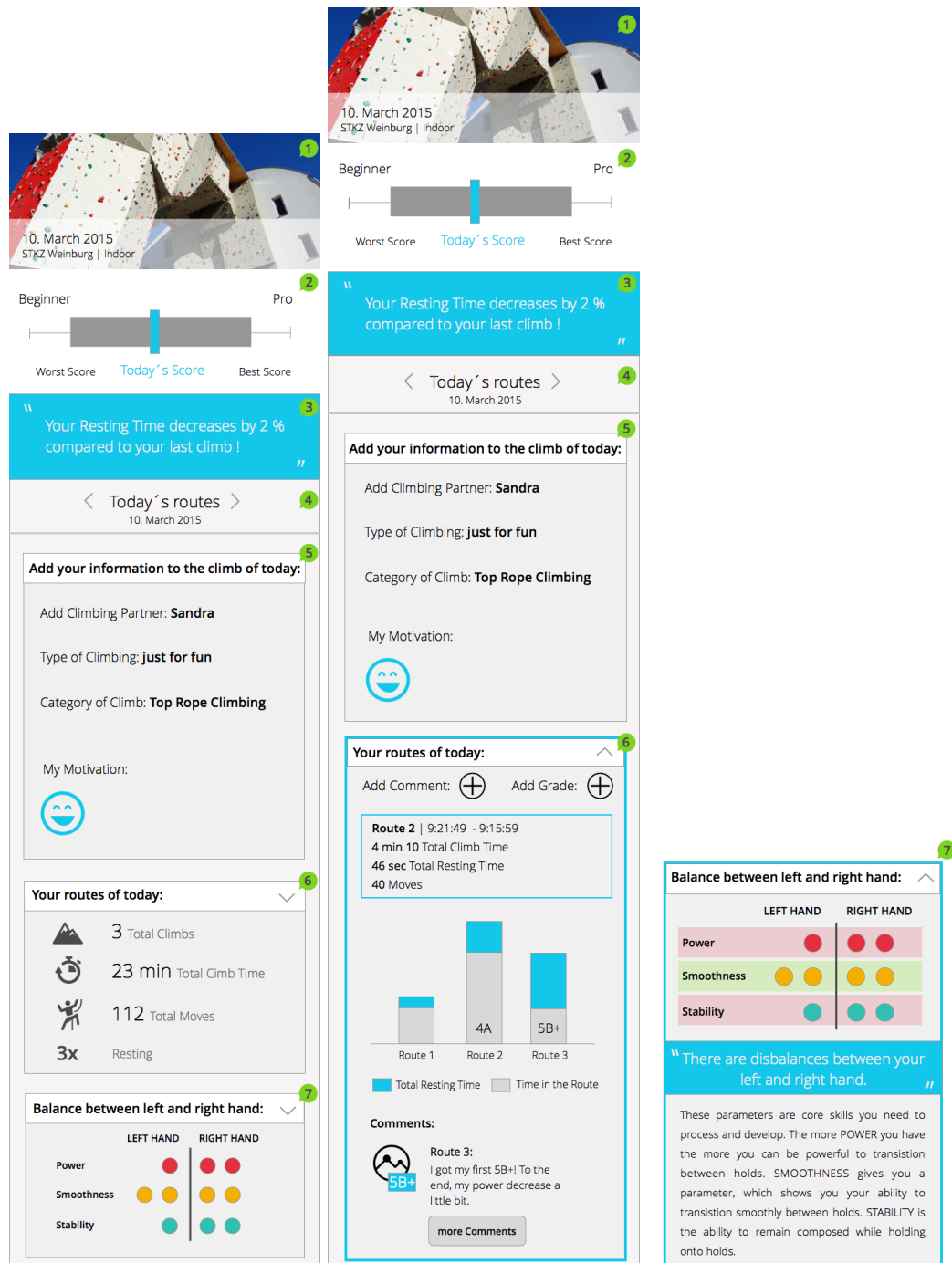


Figure 48: Concept Revision of Mobile Web Application: First screenshot illustrates the overall concept of the mobile application. The second view gives an insight into the expanded card of routes. The card showing the balance between left and right hand is displayed in the third view.

Presentation & Analysis Tool

- The colour scheme mentioned above is also applied to the web application.
- As seen in Figure 49, area 1, the climbing score visualization is implemented in the interface. The hard facts about the climbing day, such as number of routes, total climb time, moves and number of resting are positioned above the score visualization. The motivational message is also part of the view. Data added via the mobile application is displayed in the first section of the interface.
- The comment section shown in Figure 49, area 2, based on the input of climbers via the mobile web application, is part of the second area next to the stacked bar chart. The x-axis of the bar chart is renamed to routes.
- To provide more exploratory possibilities, a tab bar is integrated, illustrated in Figure 49, area 3. The user gets more information on demand and can discover new views.
- An overview of the parameters power, stability and smoothness of the right and left hand is given to the user. For more details, the vertical bar chart of the first version was redesigned to a horizontal one. The goal of detecting disbalances can be covered. Bars are grouped by routes and follows the gestalt laws of symmetry (Soegaard, 2015). Thus, the climber gets an insight into the balances related to specific routes. Figure 50 gives an impression of the visualization technique.

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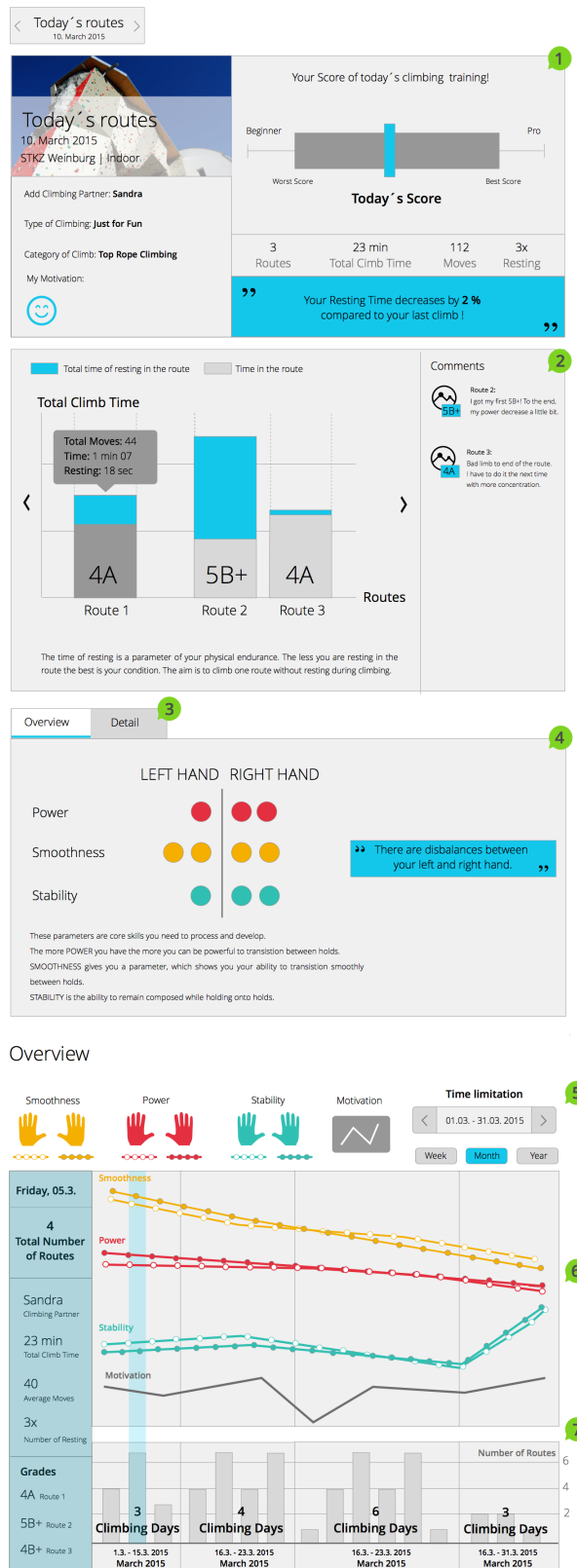


Figure 49: Concept Revision: Analysis & Presentation Tool Desktop Device



Figure 50: Concept Revision Overview Balance

- Filter possibilities are designed as icon buttons to hide and display the specific parameters for the left and right hand and the progress of the motivation. Figure 49, area 5 shows the design of the overview visualization. A white space area is implemented, seen in Figure 49 area 6, that differentiates between parameters power, stability and smoothness and the bar chart. The number of climbing days is presented as a textual element. A y-axis is implemented to the bar chart providing easier interpretation of the number of routes. To the whole left side of the visualization, an area is defined to illustrate information about a climbing day in more detail. Based on the experts' feedback, the climbing partner was integrated.

5 Prototype Implementation

The next section of the thesis deals with the implementation of a prototype. The concept based on high-fidelity wireframes was implemented in the form of a scenario-based prototype (Beaudouin-Lafon & Mackay, 2003). Only those elements of the prototype were implemented to go through the real world usage scenarios. Two different scenarios were created, described in chapter 4.5. These scenarios were also used in the usability study.

Figure 4 gives an overview of the involved components of the mobile prototype. The scenario-based prototype was implemented in HTML, CSS, JavaScript and D3.js 3.5.5 (Bostock, M. et al., 2011). The mobile web application was fully implemented in HTML, CSS and JavaScript. The interface elements are images which were made clickable by using HTML Map Areas and JavaScript. Listing 2 shows the HTML source code.

```
<div id="routenView">
  <div id="chart">
    
    <map name="barchart">
      <area shape="rect" coords="80,182,158,310"
      style="cursor:pointer" onclick="showTooltip()">
      <area shape="rect" coords="232,107,310,310"
      style="cursor:pointer" onclick="showTooltip2()">
      <area shape="rect" coords="326,200,406,310"
      style="cursor:pointer" onclick="showTooltip3()">
    </map>
  </div>
</div>
```

Listing 2. Map HTML to Implement Interactive Areas

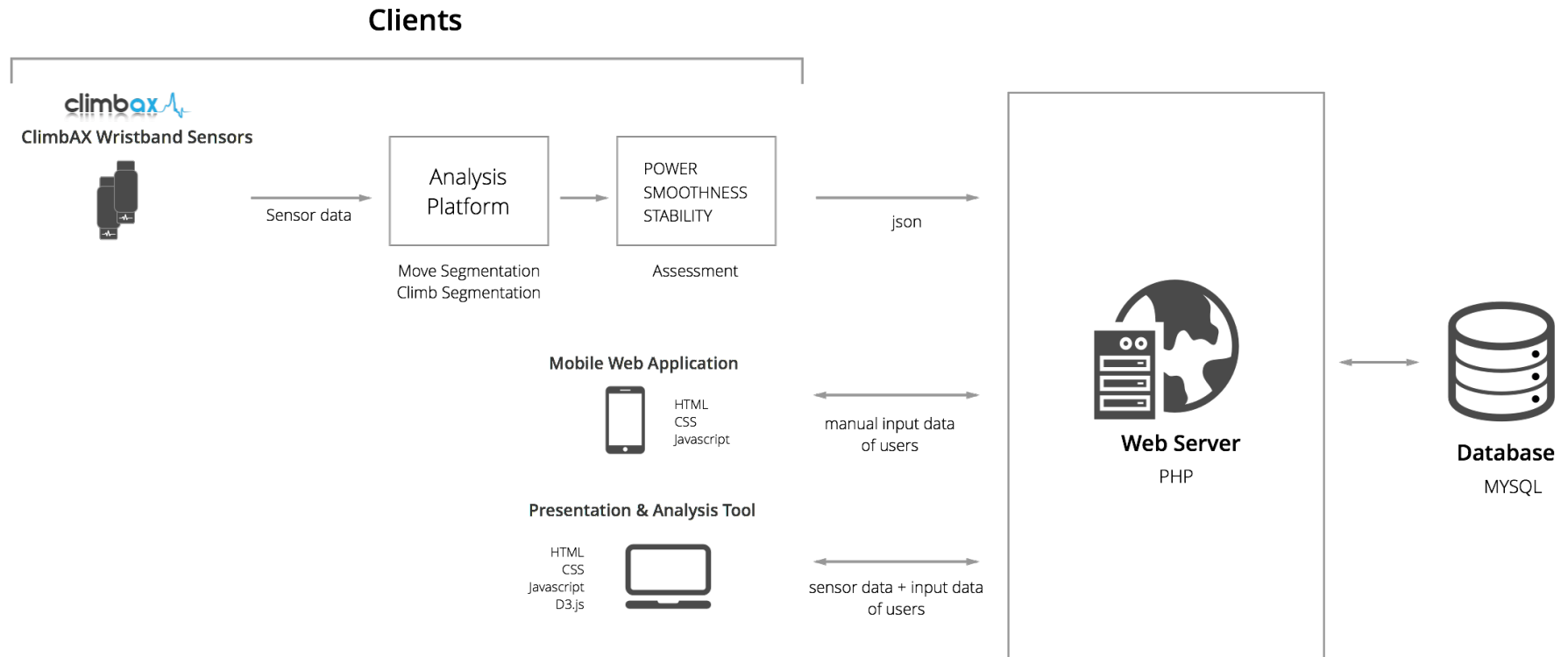


Figure 51: Overview of the Components of the Scenario-Based Prototype

5 Prototype Implementation

To save the data of the input fields, a database based on mysql was created. The climbing partner, the type and category of climbing, and the motivation was stored in the database.

The web application was also implemented in HTML, CSS and JavaScript and D3.js. The vertical bar chart, illustrated in Figure 49, was implemented in D3.js. “D3.js is a JavaScript library for creating data visualizations” (Murray, 2013, p. 7). Data-Driven-Documents – D3 – is a tool for manipulating documents based on data. The library helps to bring data to life using HTML, SVG, and CSS (Bostock, M. et al., 2011, p. 3). The emphasis of D3 is put on web standards giving the full capabilities of modern browsers. D3 allows binding data to a Document Object Model (DOM), and then apply data-driven transformations to the document.

The underlying data structure can be seen in Listing 1, described in more detail in chapter 2.2. For implementing this bar chart the attributes of the object called “Climb” was the basis. The length of each vertical bar is the value of the attributes “controlLeft”, “controlRight”, “powerLeft”, “powerRight”, “stabilityLeft” and “stabilityRight”, displayed in Listing 3. The number of groups depends on the number of sessions climbed on one day. The shown parameters for one specific route are sourced from the objects and also from the climber’s manual input.

```
"Climb": [
  {
    "session_id": 6,
    "id": 1,
    "startTime": "2013-01-09 09:14:15",
    "stopTime": "2013-01-09 09:16:36",
    "staticTime": 134.1798952,
    "controlLeft": 9.203320398,
    "controlRight": 0.5267699768,
    "numberMovesLeft": 22,
    "numberMovesRight": 8,
    "powerLeft": 4.22835615,
    "powerRight": 5.478709012,
    "speed": 9.427369843,
    "stabilityLeft": 4.177441043,
    "stabilityRight": 9.830524665
  },

```

Listing 3. JSON Structure: One Object and the Contained Attributes

5 Prototype Implementation

The next step was to parse and filter the data of the received JSON. To obtain the names and values of the attributes needed for the visualization the method `key()` and `filter()` was applied on the data set. Listing 4 shows the source code of this step.

```
var parameterNames = d3.keys(data[key].Climb[0]).filter(function
(key3) {return showParameter(key3, showRight)});
```

Listing 4. Filter and Parse Given Data

Furthermore, the `forEach()` function iterates over the associative array and maps the filtered data to a new array with the structure of name and value, summarised in Listing 5.

```
data[key].Climb.forEach(function (d) {
    d.parametersRight = parameterNames.map(function (name)
{
    return {
        name: name,
        value: +d[name]
    };
});
```

Listing 5. Creating an Array With Mapped the Data Structure

For ordering the array element by the appearance of the three parameters power, smoothness and stability, a compare function is implemented, illustrated in in Listing 6.

```
function compare(a, b) {
    if (a.name.indexOf("power") > -1) {return -1;}
    if (b.name.indexOf("power") > -1) {return 1;}

    if (a.name.indexOf("stability") > -1) {return 1;}
    if (b.name.indexOf("stability") > -1) {return -1;}
    }
    return 0;
}
```

Listing 6. Compare Function Ordering the Data

5 Prototype Implementation

The vertical bar chart is displayed in a SVG graphic. To display the parameters power, stability and smoothness, a grouped bar chart was used. Each group represents a route to the current day. To realise groups in a SVG a new g element using the `append()` method of the SVG object (Murray, 2013, p. 122) was appended. To map the data values of the parameters to new values and so scale the value to a given height and width of the SVG, different scale factors were defined.

Ordinal scales were defined to spread elements equally across a defined range ("Ordinal Scale mbostock/d3," n.d.). By clicking the icon buttons, the climber can hide or display the parameters for the right and left hand. Because of the usage of scale factors the bars adjust.

5 Prototype Implementation

```
function calculateScalesR(dataSortedRight) {
  // Scale of the group
  yGroupScaleR = d3.scale.ordinal()
    .domain(dataSortedRight.map(function (d) {
      return d.id;
    }))
    .rangeRoundBands([0, heightSVG], 0.3, 0.1);

  //Inner Group Scale parameter together
  yInnerGroupScaleR = d3.scale.ordinal()
    .domain(dataSortedRight.map(function (d) {
      return d.parametersRight.map(function (d_a) {
        return d_a.name;
      })
    }))[0])
    .rangeRoundBands([0, yGroupScaleR.rangeBand()], 0.3);

  // Width Scale: summarize all values in an array, to get maximum
  // Value. The maximum Value is the basis for the scale factor
  var allValues = [];
  for (i in dataSortedRight) {
    var routendaten =
      dataSortedRight[i].parametersRight.map(function (d_a) {
        return d_a.value;
      });

    for (index in routendaten) {
      allValues.push(routendaten[index]);
    }
  }

  widthScaleR = d3.scale.linear()
    .domain([0, d3.max(allValues)])
    .range([0, widthSVG]);
}
```

Listing 7. Function to Calculate Scale Factor Using Scales in D3.js

Discussion:

The advantage using D3.js to implement data visualization elements is the data binding mechanism. With d3, the data input values are bound to elements in the DOM. By developing the prototype mentioned above, the challenge was not to bind the data, but to bring the data in the right form. The JSON dataset had to be filtered and parsed before binding the data to the DOM elements – in that case to rect elements. The values in the dataset are unlikely to correspond exactly to pixel measurements. Scales provide a way to map those data values to new values useful for visualization purposes. To make the bars adjustable when updating the view, ordinal scales were defined. In summary, using D3.js makes it easier to create interactive data visualization, but it takes some time to work in because of the broad range of functions.

6 Prototype Evaluation

The implemented prototype formed the basis to explore usability issues in the particular domain of climbers. The prototype covers the different interactive parts where users can perform tasks and interact with the system.

6.1 Method

The user-based usability study was conducted to test high-level design choices on the basis of the implemented prototype. A qualitative observational usability study was performed to learn the complexities of when and why a visualization technique works or does not work (Tory, 2014). Because of the qualitative character a personal questionnaire was conducted at the end of the usability test. During the test, the Thinking Aloud (Van Someren et al., 1994) approach was followed.

The main purpose of this study was to improve the quality of the visualization techniques and interaction design concepts by finding flaws in them (Lazar et al., 2010, p. 256). Also, an evaluation of the effectiveness and helpfulness of the developed concept was an aim of the usability study. This evaluation study should also assess the strengths and weaknesses, and limitations of the visualization techniques and interaction techniques. The design of the concept was based on a particular domain problem, which had to be evaluated to identify ways to improve the design. The concept based on a mobile web application and an analysis and presentation tool should meet the requirements and also provide a self-assessment tool for climbers.

6.2 Procedure

The usability study was performed in a laboratory environment in the STKZ Weinburg (Therapeutic Climbing Centre), Lower Austria from April 13 and 14 2015. The data collection method were limited to direct observations and questionnaires (Tory, 2014, p. 418). Video recording logged the interactions with the system and also the feedback of the subjects. During the direct observation, handwritten notes were taken. Test devices were a Nexus 5 (Android 5.1, CPU: Qualcomm Snapdragon™ 800, 2,26 GHz, 2 GB RAM) and a MacBook Pro 13 (OS X 10.9.5; 2,3 GHz Intel Core i5; 4GB RAM) inches. On the MacBook Pro the browser Chrome in the version 42.0.2311.135 is installed. The Chrome version 42.0.2311.111 was the test browser on the Nexus 5 device. The mobile web version was the first subject of inspection; then the web application was tested. First an introduction was given to the climbers and then they had to perform different tasks. The tasks were derived from the scenarios, defined for the prototype implementation. The participants were asked to speak out on their problems and needs while performing the tasks. In the last part of the usability study, a questionnaire was distributed. The introduction and the actual test took 20 minutes, and the questionnaire should not exceed 15 minutes.

6.3 Participants

The target audience consists of climbers of all ages, who are interested in new technological devices. The level of training or time since climbing is no exclusion criterion. The target group should be interested in new media and technologies. Experiences related to the usage of quantified-self applications or systems are not required. Based on the study of Nielsen (1993), just five users find 80 percent of the usability problems. Therefore, five people from the target group were recruited for the usability study. Table 3 gives an overview of the participants in the usability test:

Participant	Age	Gender	Climbing for	Experience with Sport Applications
TP 1: Petra	44	Female	4 years	sportschecker application for running
TP2: Jasmin	23	Female	6 years	-
TP3: Lukas	19	Male	8 years	Runtastic, cyctastic for running and cycling
TP4: Dominik	23	Male	6 years	Suunto heart rate monitor watch for running and cycling and mountaineering
TP5: Emina	23	Female	7 years	-

Table 3: Participants of the Usability Test

6.4 Study Design

6.4.1 Tasks and Scenario – Mobile Web Application

The scenario mentioned below was the basis for the mobile application test and is used to give the participants a situation that is similar to a real world situation. The test design and guidelines for this usability study can be found in the Appendix C.

Scenario for the mobile application:

After climbing with your friend, you have to wait in the changing cubicle. During the waiting time, you analyse the climbing day by using the mobile application on your smartphone. Since the launch of the wearable devices by ClimbAX, you have been using those for documenting your climbing. The data transfer to the mobile application is based on Bluetooth.

Task 1 – Climbing status:

See the climbing status of today. **Please, describe your climbing condition of today.**

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?

Task 2 – Data Input:

Add the name of your climbing partner, choose a category and type of climbing and define your status of motivation. **Please save your inputs.**

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?
- Did the participants repeat any interactions?

Task 3 – Routes:

Inspect your routes in more detail. **Please, describe the duration and resting time of the second climb.**

Please describe how you will add a grade and a comment to the first route.

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?
- Did the participants repeat any interactions?

Task 4 – Balance between right and left hand:

Furthermore, you are interested in the balance between your left and right hand. Navigate to the view and open it. **Please explain what you see.**

Measurable parameters:

- Was any assistant necessary to solve the task?
- Are there false assumptions apparent?
- Do participants express displeasure while solving tasks?
- Did participants repeat any interactions?
- Can participants describe the parameters power, smoothness and stability?

6.4.2 Tasks and Scenario Presentation and Analysis Tool

Scenario for the web application:

During your analysis, you identify a disbalance between your right and left hand related to your power. You have decided to look through the data at home on your laptop device. You open the website and start to analyse the data.

To evaluate the mobile version and the web application in each case 4 tasks each are given to the participants of the study.

Tak 1 – Overview Routes:

Analyse the progress of the routes. **Please, explain the visualization.**

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?

Task 2 – Balance Overview:

The progress of the parameters over one climbing day is the aim of your analysis. Navigate to the overview section. **Please describe what you can see.**

Measurable parameters:

- Are there false assumptions apparent?
- Do participants express displeasure while solving tasks?

Task 3 – Balance between Right and Left Hand:

During the last route, you realised that your power had decreased. So you want to analyse the corresponding information. Navigate to the appropriate visualization. **Please tell me if the right and left hand is in balance during your third route. To detect this, display and hide the parameters, as you needed to do for your analysis.**

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?

Task 4 – Overview Visualization:

You have tried to exercise and become better. You are interested in the trend of your physical condition over the last month. **Please describe the progress of your climbing day related to the number of climbing days and number of routes.**

Show me how you change the time to a year view.

Hide the left hand of the parameter “Power”. Show me how you will interact.

Please, describe the progress of the parameter Power.

Measurable parameters:

- Was any assistance necessary to solve the task?
- Are false assumptions apparent?
- Do participants express displeasure while solving tasks?

6.4.3 Questionnaire Design

The design of the questionnaire section contains different open questions to get an insight into users' satisfaction with the system and also find problems and receive feedback. The first two questions focus on the test implementation and assessment of the tasks given. The next questions are defined to detect problems and elements that have to be adopted from the participants' point of view. A further question is integrated to find the preference and usage situations in which this system can be integrated into the participant's training.

Those questions were asked about both prototypes immediately after the practical part of the user test.

6.5 Test Results

In general the findings are divided into feedback and problems. For each of these two areas there is another scale to evaluate. The used scales and the obtained feedback as well as the problems are presented in this chapter.

The two factors *Added Value* and *Effort* are used to prioritise the feedback. A 1 to 3 scale is defined for each of the factors. The Added Value factor is defined as how much the feedback given by the test subjects would improve the application. A categorisation of the effort provides an indication of how much effort would have to be spent to implement the given user feedback into the system.

Added Value:

1 = no added value: it is a nice-to-have feature;

2 = Added value: could improve the user experience of the user when implemented

3 = significant added value: best user experience and satisfaction; should be given high priority; must be necessarily integrated into the system

Effort

1 = little effort to implement

2 = average effort to implement

3 = high effort to implement

To categorise the problems identified in the usability study two factors were defined: Severity and Effort. A 1 to 3 scale is developed for each of the categories. The severity of a usability problem is a combination of three factors: frequency, impact and persistence ("Severity Ratings for Usability Problems: Article by Jakob Nielsen," 2015). The effort can be described as how much time would have to be spent to implement the given user feedback into the system. The given rating scales were adopted based on the 0 to 4 rating scale defined by Nielsen ("Severity Ratings for Usability Problems: Article by Jakob Nielsen," 2015).

Severity

1 = minor usability problem: do not affect the user experience

2 = major usability problem: important to fix; average impact on the usage of the system

3 = usability catastrophe: necessary to fix because the problem affects the user experience and the usage of the system

Effort

1 = little effort to implement

2 = average effort to implement

3 = high effort to implement

Each prototype was evaluated based on four tasks. The results, as shown in Table 4, indicate that task 1, 2 and task 4 could be performed without any assistance. Participant 2 had some issues related to the interaction with the given bar chart. Tasks defined for the web application could be mostly performed without any assistance, summarised in Table 5. Participant 2 and 3 needed some assistance to find the appropriate visualization. Also test person 5 needed help concerning the interaction with the visualization showing balances of right and left hand based on the parameters power, smoothness and stability.

Participant 4 and 5 had to be given some assistance to complete the tasks of displaying detailed information about a particular climbing route.

Mobile Web Application:

Test Person	Task 1 Climbing Status	Task 2 Data Input	Task 3 Routes	Task 4 Balance between right and left hand
1				
2				
3				
4				
5				

Table 4: Tasks overview – Needed Assistance to Complete Task on Mobile Web Application; Green: no assistance needed; Red: assistance needed

Presentation & Analysis Tool:

Test Person	Task 1 Overview Routes Visualization	Taks 2 Balance Overview	Taks 3 Balance between left and right hand	Task4 Overview Visualization
1				
2				
3				
4				
5				

*Table 5: Tasks Overview – Complete Task with Assistance on Web Application
Green: no assistance needed; Red: assistance needed*

The overall response was very positive because none of the participants expressed displeasure. It is apparent that all participants did not perform their interactions more often to achieve their goals.

It can be seen from the data in Table 6, that some false assumptions were met in different parts of the prototype. The input area of the mobile web application was interpreted as the data stored of the last training. The participants did not recognise that the input space would be filled out after climbing or before climbing. The subjects reported that the visualization displaying the today's climbing score was unclear at first. Test person one also had problems with analysing the climbing score visualization. However, participants were able to read and interpret the visualization after being given some hints. Just over half of the participants had problems with interpreting the colours within the visualization of the balance between left and right hand. These colours are based on traffic light schemata which highlight balances and disbalances between left and right hand of a climber. All participants indicated that they were not sure if they could interpret the parameter „Smoothness“ in a right way. After providing them with a short description, they got an idea and categorised it as a necessary skill of a climber.

False assumptions	TP1	TP 2	TP3	TP 4	TP5
Input possibility mobile web application	x				
Score visualization	x	x			
Traffic light colours – highlighting disbalances of left & right hand on the mobile web application	x	x		x	
Smoothness Parameter – meaning related to climbing	x	x	x	x	x

Table 6: False Assumptions

6.5.1 Problems & Feedback Mobile Web Application

The problems and feedback from the participants were categorized based on the defined schemata. Table 7 gives an overview of the problems found and table 8 reported feedback related to the mobile web application. The next section of the thesis points out the problems and feedback in more detail.

Problem	Severity	Effort
Climbing status interpretation	2	2
Highlighting disbalances using colours	1	1
Arrow Icon expand Card View	3	1

Table 7: Categorization of Identified Problems from the Participants

Feedback	Added Value	Effort
Illustrate breaks between climbs in more detail	3	2
Implementing menu to reduce information overload	2	3
Convert grade standards	2	1
Give useful tips for exercises to improve climbing movements	3	3

Table 8: Categorization of Identified Reported Feedback from the Participants

Problem 1: Climbing status interpretation – Task 1

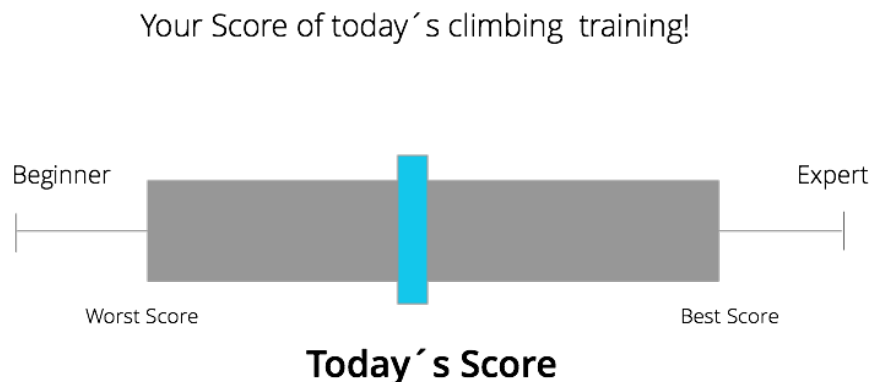


Figure 52: Score Visualization

Participants had problems with interpreting the climbing status at one glance, as presented in Figure 52. After working through task 1 (explaining the climbing status of today's climbing day), all climbers were able to interpret the status without any assistance. Participant 1 argued that the visualization is not useful for her personal valuation. Four subjects categorised the visualization as necessary and beneficial. The severity was defined as a „major problem“ because it is the central part of the interface and should give climbers a first impression of their training level. The effort to fix the problem is defined as average because new visualization techniques have to be created, which should be tested by the target group.

Solution approach for problem 1

Your Score of today's climbing training!



Figure 53: Score Visualization

The information was divided into two visualizations. Figure 53 shows the new view, based on two bars. The first visualization shows an assessment based on the parameters Beginner or Expert. Secondly, the worst and best scores were compared to the today's climbing score. Based on this approach, an integration of last climbing scores such as the score of the last climbing day could be integrated.

Problem 2: Highlighting disbalances using colours – Task 4

Three out of five participants were not able to recognise highlighted parameters in the view showing balances between left and right hand. They associated the background colour with the meaning of the parameter. The parameter "Power" was interpreted as strength. Therefore, the background is red. In this case, a wrong assumption could be recognised. The severity is defined as „minor usability problem“ because an interpretation of the parameters can be conducted. A little implementation effort is identified to amend this visualization.

Solution approach for problem 2

By removing the given colours, an improvement can be achieved. All participants were able to interpret the visualization without knowing the meaning of the colours. Figure 54 displays the improved visualization.

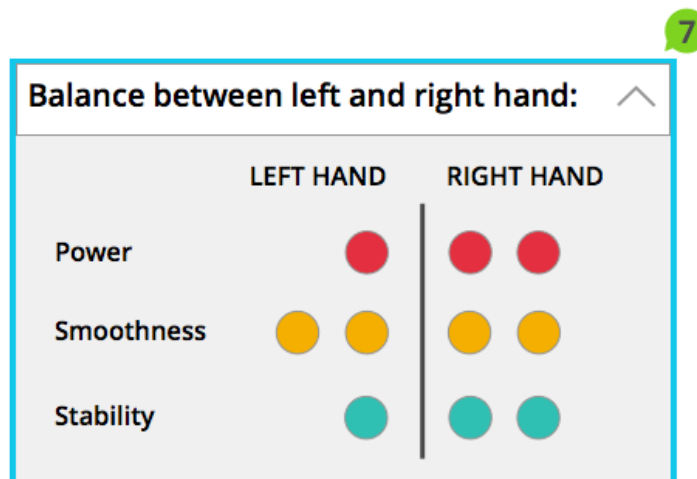


Figure 54: Balance Between Left and Right hand Solution for Problem 2

Problem 3: Highlighting disbalances using colours – Task 3

Regarding Task 3, most of the participants tried to expand the view by tapping on the first icon, shown in Figure 55. After failing, they noticed the expand possibility by tapping on the icon. This problem is ranked as “usability catastrophe” but little implementation effort is needed to fix the problem. If users are not able to get detailed information, the user experience and satisfaction will decrease.

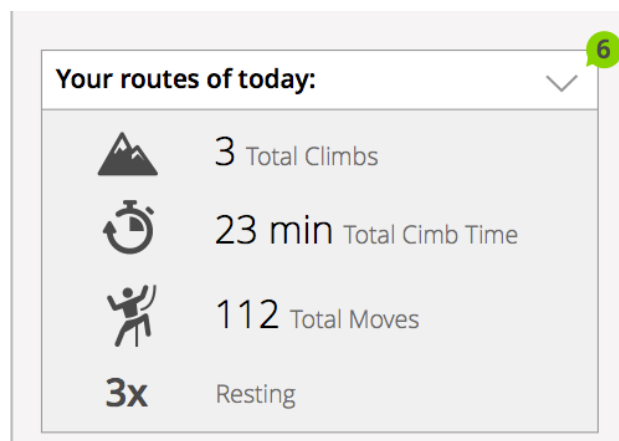


Figure 55: Expand Card

Solution approach for problem 3

The prototype only provides the possibility to expand the card by tapping the arrow icon or the white area. By implementing a fully expand functionality by tapping on this particular section itself and changing the icon, the problem can be solved.

Feedback 1: Illustrate breaks between climbs in more detail – Task 3

Participants reported on the importance of displaying breaks between climbs. Participant 1 argued that the breaks should be rasterised, based on 5-minutes sequences. Also test person 4 and 5 addressed the need of giving detailed information of breaks. The information "total time of one climbing day" could be integrated to give a reference number to the total climb time, which defines the time being on the route. Because of the significance of all climbers the feedback can be prioritised as significant added value with an average effort to implement this into the system.

Solution approach for Feedback 1

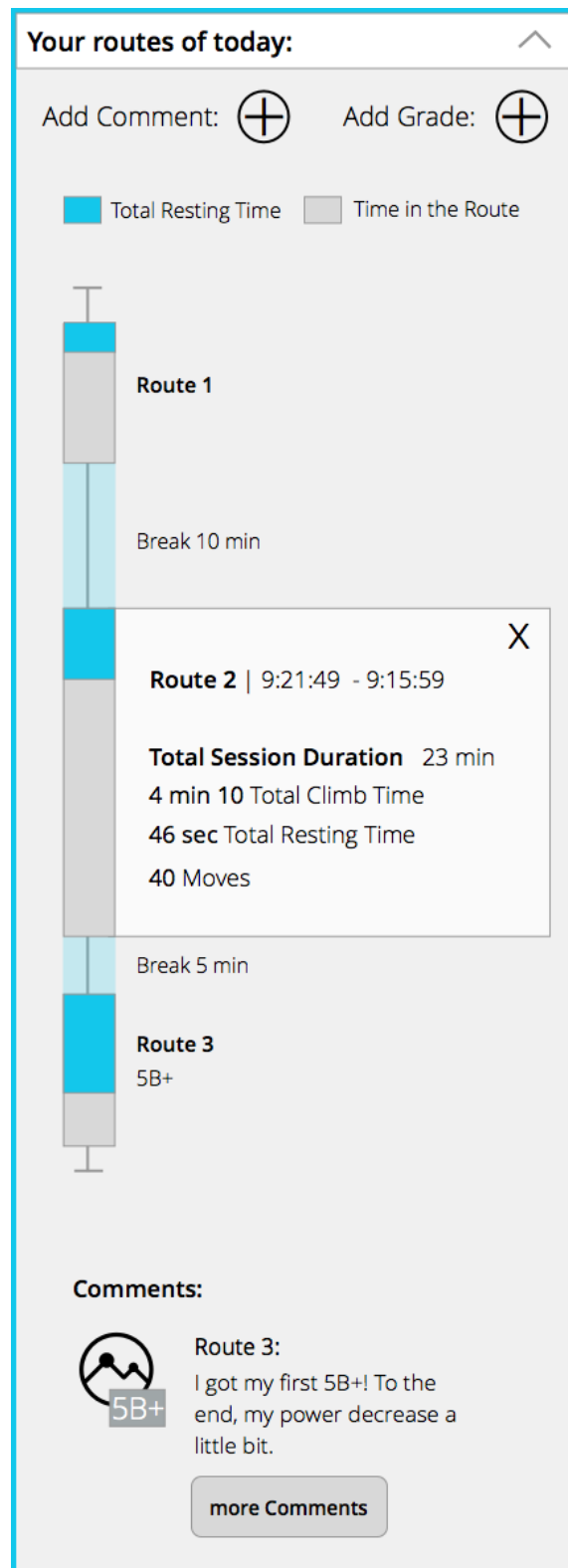


Figure 56: Route View Timeline Visualization

To satisfy the need of the climbers, showing breaks between routes, a timeline visualization in combination with stacked bars was designed (cf. Figure 56). An area appears which contains information such as total climb time, a number of moves, total session duration and total resting time by tapping a bar in the visualization. The user can navigate through the routes by scrolling the timeline view.

Feedback 2: Convert Grade Standards – Task 3

Participants commented on converting grade standards related to the input of grades to one climb. This feature can be implemented easily and can improve the user experience and usage of the system.

Feedback 3: Implementing a menu to reduce information overload – Task 3

Participant 4 underlined the need of a menu to reduce information overload. A menu would provide the benefit of exploring the data and concentrating on one aspect of information or visualization of interest. Only one of the five test subjects commented on this need. The majority of the climbers preferred the vertical card view. In order to come to a decision about implementing a menu, several tests and interviews with a larger number of people of the target group would have to be conducted. If the large proportion of climbers expressed the wish for a menu, it should be implemented into the interface. Adding a menu to the system possibly means an improvement of the user experience but also a high effort to implement.

Feedback 4: Giving useful tips for exercises to improve climbing movement – Task 4

When the participants were asked about the importance of being given tips and motivational messages, the majority commented that the system should give tips to improve their movement and strength of their arms and fingers. One participant added that the tips had to be based on sports scientific exercises. Based on the feedback from the participants, the need of giving tips based on physical activities could be identified. An implementation of this feature generates a significant added value for users. The system can assess the climbing training and can give useful tips. A high effort can be prioritised for implementing intelligent features to the system. Studies and technical research have to be done to make meaningful suggestions based on the training performance.

6.5.2 Problem & Feedback Presentation and Analysis Tool

Table 9 gives an overview of the problems found and table 10 reported feedback related to the web-based presentation and analysis tool. The next section of the thesis points out the problems and feedback in more detail.

Problem	Severity	Effort
Detail View - balance between left & right hand – buttons	2	1
Interaction: Get detailed information about one climbing day – overview visualization	2	2
Missing headings related to the time	3	1

Table 9: Problem Identified in the Presentation and Analysis Tool

Feedback	Added Value	Effort
Illustrate breaks between climbs in more detail	3	2
Display Total Session Duration – Overview Visualization	3	1
Giving a Reference – detail view of balance between left & right hand	2	1

Table 10: Feedback to the Presentation and Analysis Tool

Problem 1: Detail View: Balance between left & right hand – Task 4

The visualization seen in Figure 57 displays balances or disbalances between the right and left hand compared to each route of one climbing day. The interaction possibility with the visualization by tapping the button to hide or show bars was recognized by four participants. Test person 4 tried to hide one parameter by tapping the bar. With assistance, the user was able to solve the task. This problem needs to be fixed because it can affect user experience but can be ranked as little implementation effort.



Figure 57: Balance Visualization Button Interaction

Solution approach for problem 1

The implementation of the function to hide and show parameters by tapping a bar can be additionally be implemented to the system providing two different possibilities to interact with the chart. The observations have shown that participant 4 became nervous when trying to hide one parameter by clicking on a bar and nothing happened. So it needs to be tested with a larger number of people of the target group to get relevant feedback on this problem.

Problem 2: Interaction: Get detailed information about one climbing day – overview visualization – Task 4

Participant 4 and 5 needed assistance to get detailed information about one climbing day. The observation has shown that subject 2 and 3 had to reflect for a long time before tapping on a bar to get the right information based on the task. It should be noted that only the first three bars of the bar chart were linked.

Solution approach for problem 2

To improve the visualization the first day of the month could be highlighted, so that user recognises the interaction possibility at one glance.

Problem 3: Missing headings related to the time and date – Task 3

Different participants had some issues to know which visualization refers to which day. This means that subjects were confused and disoriented. Participant 2 and 3 scrolled over the visualizations and could not detect the right visualization to complete the task. The chart itself could be interpreted without any problems.

Solution approach for problem 3

To improve the interface and give the users some orientation relating to the time and reference to information, headings as well as navigation bars were implemented. Figure 58 and 59 represent the interface design based on the implemented issues mentioned above. A navigation bar at the top of the page was defined. The user can switch between today's climbing day and overview. Based on this concept the information was splitted and therefore the user can concentrate on one aspect of the data. This way, the overload of information can be reduced.

6 Prototype Evaluation

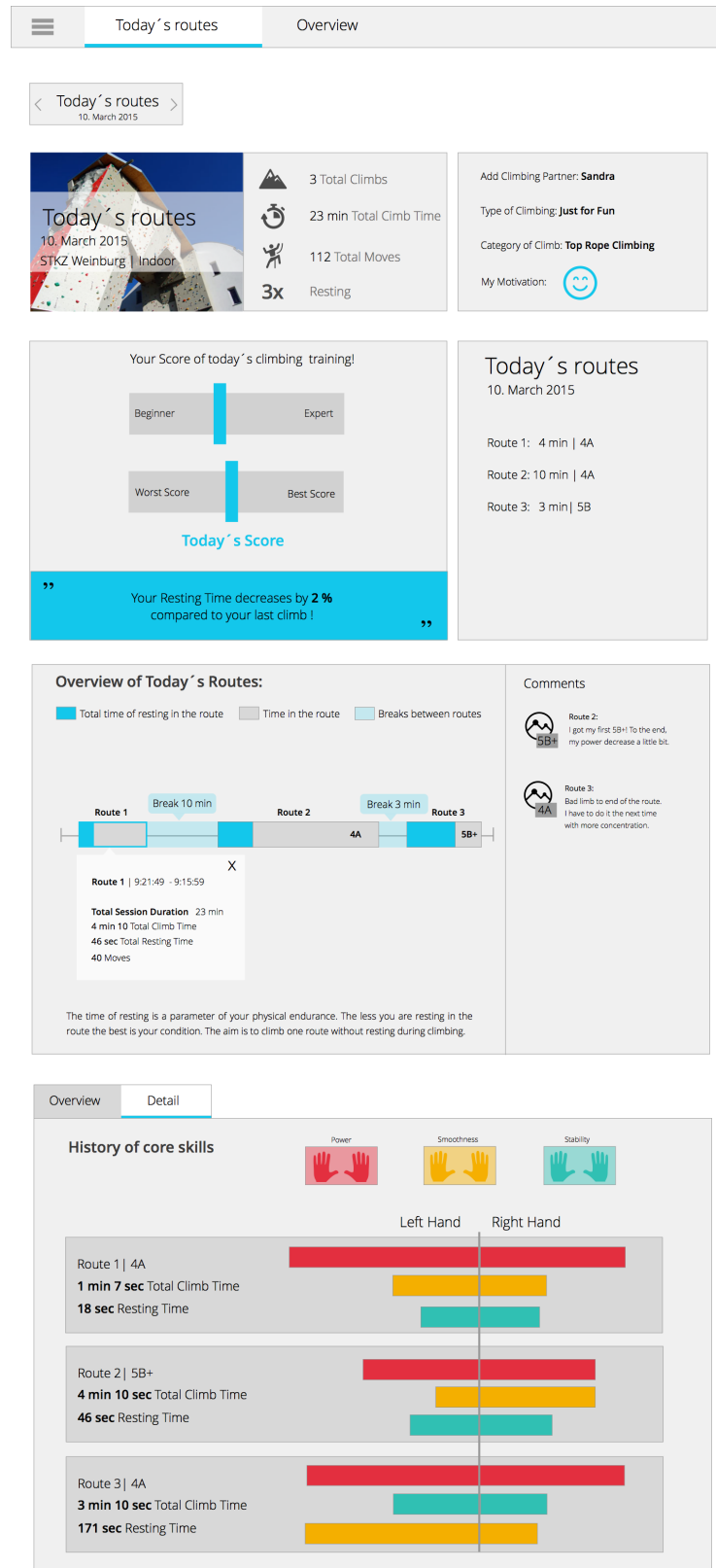


Figure 58: Revised Web Presentation Tool Interface Design

6 Prototype Evaluation

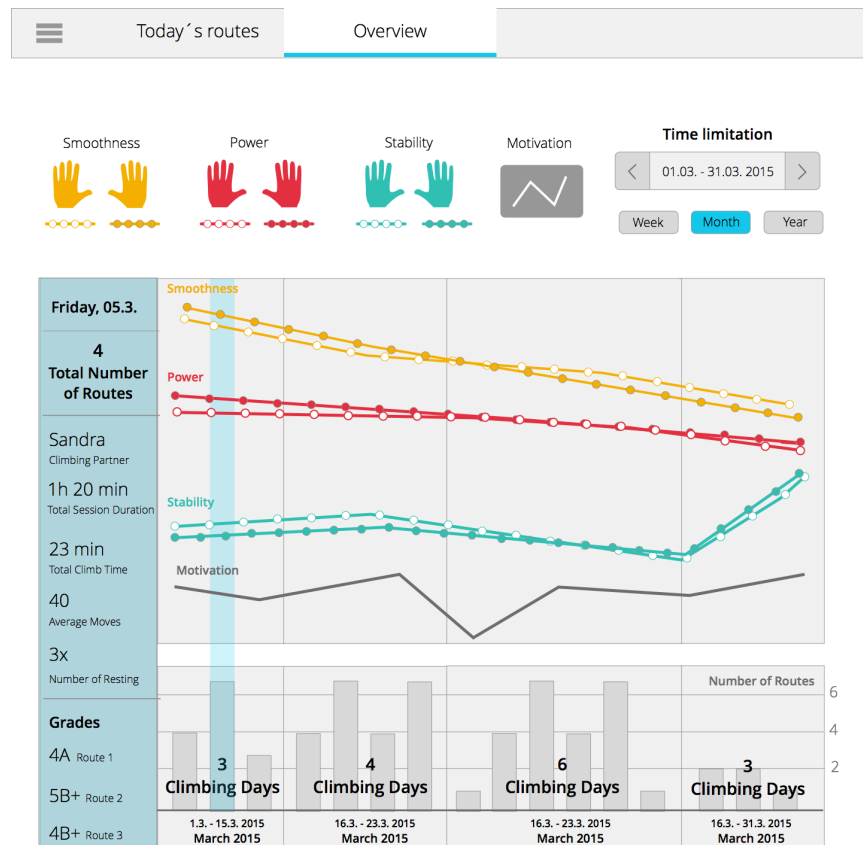


Figure 59: Web Visualization Overview Section

Feedback 1: Illustrate breaks between climbs in more detail – Task 2

Participants mentioned the importance of displaying breaks between climbs also via the web application. Because of the significance of all climbers the feedback can be prioritised as significant added value with an average effort to implement this feature into the system. To satisfy the need of the climbers, showing breaks between routes, a timeline visualization in combination with stacked bars was implemented, as showed in Figure 60. By tapping a bar, an area appears which contains information such as total climb time, number of moves and other relevant data. The user can navigate through the routes by scrolling the timeline view horizontally. The breaks were highlighted between the bars and by hovering a tooltip appears, illustrating the minutes of breaks between the routes.

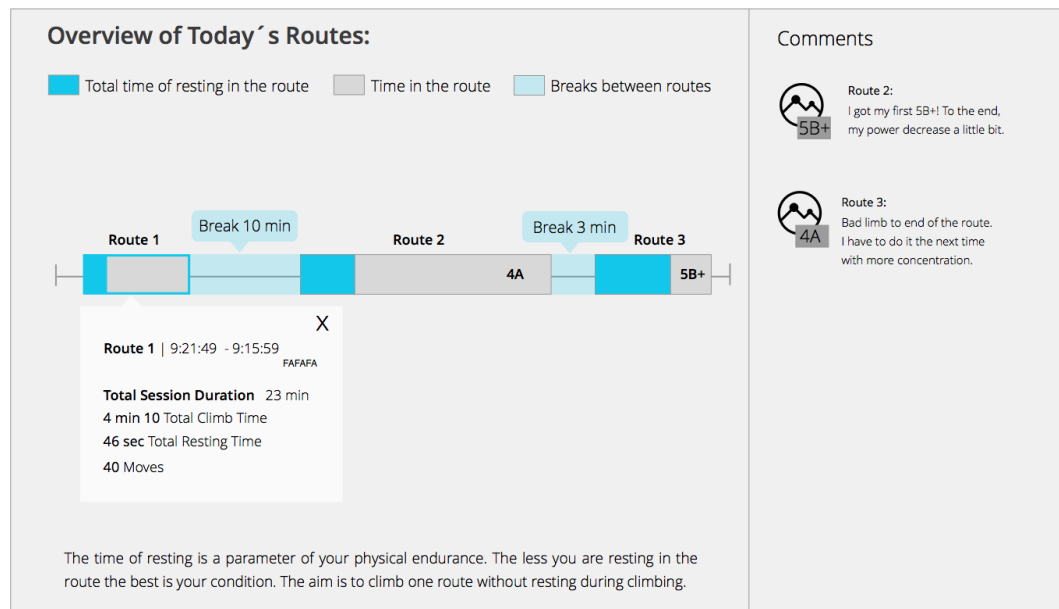


Figure 60: Route View with Integrated Break Visualization

Feedback 2: Display Total Session Duration Overview Visualization –Task 4

Participant 5 addressed the need of being given information about total session duration. This way climbers can compare their climbing time to total session duration. This information is detected by the wrist-worn sensors and can be integrated easily into the visualization of the overview visualization. Figure 61 illustrates the modifications.

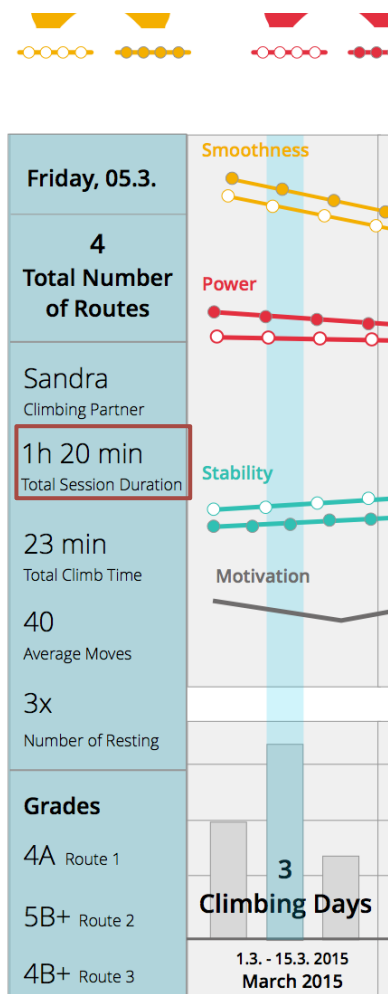


Figure 61: Integration of the Information "Total Session Duration"

Feedback 3: Giving a Reference – detail view of balance between left & right hand – Task 4

All participants were able to interpret the visualization correctly, but test person 4 indicated the need of some reference numbers or units. The person argued that detailed information was needed to analyse the data in a correct way.

As seen in Figure 62, a grid and units were added to the chart to meet climbers needs and give them the possibility to interpret the charts at one glance.



Figure 62: Balance View – Unit & Grid Integration

6.5.3 Questionnaire Analysis and Overall Feedback

In all cases, the interviewees categorised the tool as clean and very useful. The shown information, the combinations and used visualization techniques were ranked valueable. Moreover, the first impression of the mobile application and web application was positive. All participants categorised the interface as structured.

The tasks were easy to complete, and the participants said that they were able to orientate themselves fast. Only one out of five interviewees expressed the need for a menu by putting it as follows:

“I was overwhelmed by the information on the mobile application. I expected a menu where I can explore the data I am interested in.” (TP4)

Related to the used visualization techniques the bar chart illustrating the routes was categorised as useful by all participants. All participants stated that they were able to read and understand the visualizations very fast.

Some interviewees argued that the visualization at the very beginning of the mobile application illustrating the climbing scores was interesting and quite useful while others preferred a visualization showing information about the last climbs.

Asking participants about their favourite visualizations and areas of the mobile web application, the balance visualization giving detailed information based on the climbed routes was favoured. The overview of climbed routes in the form of a bar chart was categorised as interesting and useful. The design and colours used in the interface were emphasized in a positive way. Also, the input possibilities were ranked as very easy to use and to enhance the system. Giving the user the possibility to add comments to individual routes was regarded as very useful features of the system. Tips integrated within the system were categorised as an excellent feature, which is especially attractive for beginners. All participants addressed the design and content of the tip:

“The suggestions have to be designed to give examples of exercises improving the strength of hands and feet on the basis of sports science.” (TP3, TP4)

Participant 1 classified the visualization giving an insight in today's climbing score as unattractive. According to her, it would be more useful to provide information about last climbing days and explore trends and performance increases over the last month or weeks. One interviewee commented on the detailed balance view:

“The balance between left and right hand is not essential for myself. A listing of all climbing days would be useful information.” (P2)

Participant 2 mentioned the integration of adding training sessions besides climbing. The aspect of measuring the heart rate additionally to the information detected by the wrist-worn devices by ClimbAX could be an interesting indicator for sport climbing and performance assessment as well.

Subjects were asked to find areas which need to be improved. The following answers were given:

Two out of five participants hinted at the English language and emphasised the importance of a German version of the system. This feedback can be implemented very easily and would enhance the application for climbers. During the state of the art research, it has been found out that the majority of applications are in English, so the need for a system in German language can be confirmed.

Giving detailed information about breaks between routes was rated as crucial and was underlined during the interviews.

Suggestions for improvements to the interface of the mobile and web application design were given:

- Integration of a search functionality based on grades or names of route via the web application
- Giving tips based on exercises improving strength and coordination
- Overview visualization showing trends over a longer period: Show or hide parameters based on both hands, no splitting into left and right hand (web application).
- Giving units to the trend lines of the parameters power, smoothness and stability (web application)
- Overview Visualization: Separating the motivation from the trend lines of the parameters (web application)
- Filter possibility related to the category of indoor and outdoor climbing

The parameter measuring the softness of the movement was defined as “Smoothness” in the interface design. All participants assured their understanding of the parameter by asking about the validity. These views emerged mainly in relation to the mobile web application.

6 Prototype Evaluation

The mobile device was identified as the preferred one. The web application would be used to get detailed information. All participants could imagine integrating the wearable devices and both platforms into their climbing training.

7 Conclusion & Future Work

In this thesis, a concept and technical prototype was created to visualize detected data of wrist-worn sensors developed by ClimbAX (Ladha et al., 2013) and manual data input from a mobile web application. The developed system gives insights into training data and provides assessments of climbing training. The relevance of a quantified-self system for climbers is clearly supported by the current findings. There is much research done in the field of quantified-self for tracking daily activities of the users and only little work on wearable devices which support the athlete during and after the training session. The state of the art research, seen in chapter 3, also yielded various quantified-self applications for different sport such as running, cycling or strength training (“Endomondo – Laufen & Radfahren,” 2015; “Meet Moov,” 2015). However, no applications or systems for climbing athletes are available on the market. Sensor data of wrist-worn devices, collected and developed by ClimbAX, are the basis for this whole thesis. Next, the research questions, prepared in the course of this thesis are answered.

- What are the requirements of climbers?

This research question is answered in chapter 2.1. Series of contextual semi-structured interviews were conducted in which the needs and goals of potential users were obtained. Five people of the target group were interviewed to identify requirements. The results of this interview showed the importance of providing manual input possibilities besides the automatically detected data of the wrist-worn device. The preferred device for analysing data and getting an overview was identified as the mobile device like a smartphone or tablet. For a detailed analysis of the data, the target groups were willing to use the desktop. The findings of the interview suggested that the system had to be easy and simple to use. Visualization techniques such as bar charts, line plots as well as pie charts and donut charts were identified as well-known. For analysing and exploring performance data and the training level different information was displayed. Information with regard to the routes such as number of climbed routes, resting time, climbing partner, grade, the number of moves, total session duration and

total climb time were identified as core information. Also the documentation of daily condition was regarded as an important factor. The interviews showed that a combination of the number of climbs, the time in the route, the time between climbs as well as the grade of the routes had to be presented to the user to gain the possibility of analysing physical condition improvement.

- What are the possibilities to visually represents time-oriented, multivariate sensor data, collected by climbers to show pattern and behaviour in their training?

Based on the results of this interview and analysis of available applications in the field of quantified-self and self-assessment, a concept was developed. Chapter 4 contains the description of the developed system. The need for recording and adding different information was realised in the form of manual input possibilities via the mobile web application interface. The collected data of the sensing devices and data of the users' manual input constitute the basis for the presentation and analysis tool on the desktop device.

The concept was tested to find problems in the interface design and to get feedback on the implemented visualization techniques and displayed information. To take into account the recommendations of professionals in the domain of human-computer interaction, visualization and climbing, three experts were selected and the outcome is described in chapter 4.5. The results of the expert review were included in the high-fidelity wireframes.

Illustrating time-oriented, multivariate sensor data and showing pattern and behavior in climbing training of the athletes was achieved by the usage of known visualization techniques such as bar charts, table views and line plots. Different messages and suggestions were given to inform about and call attention to training history or unusual changes in training.

- Which interactions can be integrated into the interface concept to improve easy exploration and analysis?

This research question is answered in chapter 4.2.2 (mobile web application) and 4.3.2 (desktop version). The desktop presentation and analysis tool provides deeper insights into the data. Different interaction possibilities were implemented to improve easy exploration and analysis. Filtering parameters to limit given information and provide concentration on a specific aspect of the data were

implemented in different visualizations. A navigation concept was integrated to change views and to navigate through data over time. One visualization also contains the function to change the view depending on time providing the possibility to concentrate on the trends over one month or year.

- Are the interactive visual presentation and analysis tool as well as the mobile web application easy to understand for non-experts and effective?

This research question is answered in chapter 5 and 6. A scenario-based prototype was implemented with the web technologies HTML, CSS and JavaScript and the JavaScript library D3.js. Based on this prototype a usability study was conducted to evaluate the system with climbing athletes, to find problems and get feedback on the given visualizations. Based on the results described in chapter 6, the interactive visualization tool is easy to use and efficient. All participants indicated that the two systems were well-structured and easy to understand. Five out of five subjects were willing to integrate the systems into their climbing training. The input possibility of information such as comments, grade, as well as a climbing partner was identified as useful by the target group. Beside the given visualization techniques and information, climbers suggested the need for providing more detailed information about breaks between climbs. Constructive feedback was provided related to the integration of a search function and filter possibilities of categories such as indoor and outdoor climbing.

This study has demonstrated, for the first time, that the developed system for climbers has a real potential for self-assessment and training detection. Because of the two different platforms the climbers are independent. The system offers various visualizations giving climbers the chance to analyse their data and create models based on the displayed data. On the other hand, the system provides suggestions and motivational messages, which help users to learn more about their training level.

These findings have significant implications for the understanding of how climbers will interact with quantified-self applications and what the individual requirements for such a system are. It would be interesting to assess the effects of providing tips and motivational messages on climbers.

The research that had been undertaken for this thesis has highlighted a number of topics on which further research would be beneficial. Further research in this field should be carried out with a larger sample of participants to determine a deeper insight into climbers' needs. The prototype developed in the course of this

7 Conclusion & Future Work

thesis forms the basis and should be adopted based on the given feedback of the usability study. In addition, further qualitative tests are needed to evaluate the system. The target group consists of amateur sportsmen with a passion for climbing. Another possible area of future research would be to investigate other target groups such as professional rock climbers. The issue of exploring climbers in other countries is an intriguing one that could be usefully explored in further research.

Bibliography

adidas miCoach FitSmart: The Interactive Personal Coaching and Training System. (2015a). Retrieved February 5, 2015, from <http://micoach.adidas.com/>

adidas miCoach Smart Ball. (2015). Retrieved April 25, 2015, from <http://micoach.adidas.com/at/smartball>

adidas miCoach SmartRun: The Interactive Personal Coaching and Training System. (2015b). Retrieved February 5, 2015, from <http://micoach.adidas.com/>

adidas miCoach: The Interactive Personal Coaching and Training System. (2015c). Retrieved November 4, 2014, from <http://micoach.adidas.com/>

Aigner, W., Miksch, S., Schumann, H., & Tominski, C. (2011). *Visualization of Time-Oriented Data*. London: Springer. Retrieved from <http://link.springer.com/10.1007/978-0-85729-079-3>

All About Bouldering. (2015). Retrieved February 20, 2015, from <http://climbing.about.com/od/climbingtechniques/a/AboutBouldering.htm>

Bächlin, M., Förster, K., & Tröster, G. (2009). SwimMaster: A Wearable Assistant for Swimmer. In *Proceedings of the 11th International Conference on Ubiquitous Computing* (pp. 215–224). New York, NY, USA: ACM. <http://doi.org/10.1145/1620545.1620578>

Ballegaard, S. A., Hansen, T. R., & Kyng, M. (2008). Healthcare in Everyday Life: Designing Healthcare Services for Daily Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1807–1816). New York, NY, USA: ACM. <http://doi.org/10.1145/1357054.1357336>

Beaudouin-Lafon, M., & Mackay, W. (2003). The Human-computer Interaction Handbook. In J. A. Jacko & A. Sears (Eds.), (pp. 1006–1031). Hillsdale, NJ, USA: L. Erlbaum Associates Inc. Retrieved from <http://dl.acm.org/citation.cfm?id=772072.772136>

Bentley, F., & Tollmar, K. (2013). The Power of Mobile Notifications to Increase Wellbeing Logging Behavior. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1095–1098). New York, NY, USA: ACM. <http://doi.org/10.1145/2470654.2466140>

Bohemian Coding - Sketch 3. (2015). Retrieved May 14, 2015, from <http://bohemiancoding.com/sketch/>

Bostock, M., Ogievetsky, V., & Heer, J. (2011). D3.js - Data-Driven Documents. *IEEE Transactions on Visualization and Computer Graphics*, 17(12), 2301–2309. <http://doi.org/10.1109/TVCG.2011.185>

Bouldering Climbing Strength. (2015). Retrieved February 13, 2015, from https://play.google.com/store/apps/details?id=com.fitivity.boulder_climbing_strength

Brehmer, M., & Munzner, T. (2013). A Multi-Level Typology of Abstract Visualization Tasks. *IEEE Transactions on Visualization and Computer Graphics*, 19(12), 2376–2385. <http://doi.org/10.1109/TVCG.2013.124>

Brown, B., Chetty, M., Grimes, A., & Harmon, E. (2006). Reflecting on Health: A System for Students to Monitor Diet and Exercise. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems* (pp. 1807–1812). New York, NY, USA: ACM. <http://doi.org/10.1145/1125451.1125794>

Brüel Falmark. (2013). *Integrating smartphone and sensor data in a quantified self app* (Master Thesis). Technical University of Denmark, Department of Applied Mathematics and Computer Science / DTU Co, Lyngby, Denmark. Retrieved from http://www2.imm.dtu.dk/pubdb/views/publication_details.php?id=6634

Carousel Pattern - Design Pattern Library - YDN. (2009, July 15). Retrieved May 10, 2013, from <http://developer.yahoo.com/ypatterns/selection/carousel.html>

Choe, E. K., Lee, N. B., Lee, B., Pratt, W., & Kientz, J. A. (2014). Understanding Quantified-selfers' Practices in Collecting and Exploring Personal Data. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1143–1152). New York, NY, USA: ACM. <http://doi.org/10.1145/2556288.2557372>

Cleveland, W. S. (1993). *Visualizing Data*. New Jersey: Hobart Press.

Climbax - Demo Visualization. (2015). Retrieved March 3, 2015, from <http://www.climbax.co.uk/demo.html>

ClimbCoach - Diary. (2015). Retrieved February 11, 2015, from <http://www.climbcoach.org/climbcoach/diary>

Consolvo, S. (2012). Designing for Healthy Lifestyles: Design Considerations for Mobile Technologies to Encourage Consumer Health and Wellness. *Foundations and Trends® in Human-Computer Interaction*, 6(3-4), 167-315. <http://doi.org/10.1561/11000000040>

Consolvo, S., Everitt, K., Smith, I., & Landay, J. A. (2006). Design Requirements for Technologies That Encourage Physical Activity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 457-466). New York, NY, USA: ACM. <http://doi.org/10.1145/1124772.1124840>

Consolvo, S., Klasnja, P., McDonald, D. W., Avrahami, D., Froehlich, J., LeGrand, L., ... Landay, J. A. (2008). Flowers or a Robot Army?: Encouraging Awareness & Activity with Personal, Mobile Displays. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (pp. 54-63). New York, NY, USA: ACM. <http://doi.org/10.1145/1409635.1409644>

Consolvo, S., Klasnja, P., McDonald, D. W., & Landay, J. A. (2009). Goal-setting Considerations for Persuasive Technologies That Encourage Physical Activity. In *Proceedings of the 4th International Conference on Persuasive Technology* (pp. 8:1-8:8). New York, NY, USA: ACM. <http://doi.org/10.1145/1541948.1541960>

Consolvo, S., Libby, R., Smith, I., Landay, J. A., McDonald, D. W., Toscos, T., ... LeGrand, L. (2008). Activity Sensing in the Wild: A Field Trial of Ubifit Garden. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1797-1806). New York, NY, USA: ACM. <http://doi.org/10.1145/1357054.1357335>

Consolvo, S., McDonald, D. W., & Landay, J. A. (2009). Theory-driven Design Strategies for Technologies That Support Behavior Change in Everyday Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 405-414). New York, NY, USA: ACM. <http://doi.org/10.1145/1518701.1518766>

Cooper, A., Reimann, R., & Noessel, C. (2014). *About Face: The Essentials of Interaction Design* (4th ed.). Wiley.

Craggie - Your next adventure starts here. (2015). Retrieved November 4, 2014, from <https://www.craggieapp.com/>

Crags Climbing Log Book. (2015). Retrieved February 11, 2015, from <https://itunes.apple.com/at/app/crags-climbing-log-book/id438306815?mt=8>

Cuttone, A., Lehmann, S., & Larsen, J. E. (2013). A Mobile Personal Informatics System with Interactive Visualizations of Mobility and Social Interactions. In *Proceedings of the 1st ACM International Workshop on Personal Data Meets Distributed Multimedia* (pp. 27–30). New York, NY, USA: ACM. <http://doi.org/10.1145/2509352.2509397>

Cuttone, A., Petersen, M. K., & Larsen, J. E. (2014). Four Data Visualization Heuristics to Facilitate Reflection in Personal Informatics. In C. Stephanidis & M. Antona (Eds.), *Universal Access in Human-Computer Interaction. Design for All and Accessibility Practice* (pp. 541–552). Beijing: Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-3-319-07509-9_51

De Croon, R., De Buyser, T., Klerkx, J., & Duval, E. (2014). Applying a user-centered, rapid-prototyping methodology with quantified self: A case study with triathletes. In *2014 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)* (pp. 12–15). IEEE. <http://doi.org/10.1109/BIBM.2014.6999283>

DiSC Profile - The DiSC personality test explained. (2015). Retrieved May 8, 2015, from <https://www.discprofile.com/what-is-disc/overview/>

E10Climbing. (2015). Retrieved November 4, 2014, from <https://play.google.com/store/apps/details?id=com.e10.climbing>

Eastwood, C. A., Travis, L., Morgenstern, T. T., & Donaho, E. K. (2007). Weight and symptom diary for self-monitoring in heart failure clinic patients. *The Journal of Cardiovascular Nursing*, 22(5), 382–389. <http://doi.org/10.1097/01.JCN.0000287027.49628.a7>

Endomondo – Laufen & Radfahren. (2015). Retrieved February 12, 2015, from <https://play.google.com/store/apps/details?id=com.endomondo.android>

Endomondo – Web Platform. (2015). Retrieved April 25, 2015, from <https://www.endomondo.com/workouts/>

Fan, C., Forlizzi, J., & Dey, A. K. (2012). A Spark of Activity: Exploring Informative Art As Visualization for Physical Activity. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing* (pp. 81–84). New York, NY, USA: ACM. <http://doi.org/10.1145/2370216.2370229>

Few, S. (2006). *Information Dashboard Design: The Effective Visual Communication of Data*. O'Reilly Media, Inc.

Fichtinger, R., Mrak, M., Hochholzer, T., & Gabl, K. (2008). *Sportkletterfibel*. Österreichisches Kuratorium für Alpine Sicherheit.

Fitbit- Kabellose Aktivitäts- und Schlaf-Tracker. (2015). Retrieved October 28, 2014, from <http://www.fitbit.com/de>

Flat And Thin Are In. (2015). Retrieved April 29, 2015, from <http://www.smashingmagazine.com/2013/09/03/flat-and-thin-are-in/>

Fogg, B. J. (2002). Persuasive Technology: Using Computers to Change What We Think and Do. *Ubiquity*, 2002. <http://doi.org/10.1145/764008.763957>

Fritz, T., Huang, E. M., Murphy, G. C., & Zimmermann, T. (2014). Persuasive Technology in the Real World: A Study of Long-term Use of Activity Sensing Devices for Fitness. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 487–496). New York, NY, USA: ACM. <http://doi.org/10.1145/2556288.2557383>

Fyffe, A., & Peter, I. (1997). *The Handbook of Climbing* (2nd Revised edition edition). London: Pelham Books.

Garmin Connect. (2015). Retrieved April 25, 2015, from <https://connect.garmin.com/de-DE/>

Garmin Connect™ Mobile – Android-Apps auf Google Play. (2015). Retrieved April 25, 2015, from <https://play.google.com/store/apps/details?id=com.garmin.android.apps.connectmobile&hl=de>

GOLD Mitgliedschaft | Runtastic - makes sports funtastic. (2015). Retrieved November 10, 2014, from <https://www.runtastic.com/de/premium-mitgliedschaft/info>

Grober, R. D. (2010). An Accelerometer Based Instrumentation of the Golf Club: Comparative Analysis of Golf Swings. *arXiv:1001.0761 [physics]*. Retrieved from <http://arxiv.org/abs/1001.0761>

Harris, R. L. (1999). *Information Graphics: A Comprehensive Illustrated Reference*. New York, NY, USA: Oxford University Press, Inc.

Hogenboom, A. (2014). Digicoach: a digital coach for self-tracking athletes. In *Proceedings of the Chi Sparks 2014 Conference* (pp. 145 – 146). Hague: The Hague University of Applied Sciences and Chi Nederland.

Horst, E. J. (2008). *Training for Climbing, 2nd: The Definitive Guide to Improving Your Performance* (2nd ed.). Falcon.

King, A. C., Ahn, D. K., Oliveira, B. M., Atienza, A. A., Castro, C. M., & Gardner, C. D. (2008). Promoting physical activity through hand-held computer technology. *American Journal of Preventive Medicine*, 34(2), 138–142. <http://doi.org/10.1016/j.amepre.2007.09.025>

Klasnja, P., Consolvo, S., & Pratt, W. (2011). How to Evaluate Technologies for Health Behavior Change in HCI Research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3063–3072). New York, NY, USA: ACM. <http://doi.org/10.1145/1978942.1979396>

Ladha, C., Hammerla, N. Y., Olivier, P., & Plötz, T. (2013). ClimbAX: Skill Assessment for Climbing Enthusiasts. In *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (pp. 235–244). New York, NY, USA: ACM. <http://doi.org/10.1145/2493432.2493492>

Larsen, J. E., Cuttone, A., Jørgensen, S. L., Larsen, J. E., Cuttone, A., & Jørgensen, S. L. (2013). QS Spiral: Visualizing Periodic Quantified Self Data. In *Proceedings of CHI 2013 Workshop on Personal Informatics in the Wild: Hacking Habits for Health & Happiness*.

Lazar, D. J., Feng, D. J. H., & Hochheiser, D. H. (2010). *Research Methods in Human-Computer Interaction*. John Wiley & Sons.

Li, I. (2009). Beyond Counting Steps: Using Context to Improve Monitoring of Physical Activity.

Li, I., Dey, A., & Forlizzi, J. (2010). A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 557–566). New York, NY, USA: ACM. <http://doi.org/10.1145/1753326.1753409>

Li, I., Dey, A. K., & Forlizzi, J. (2011). Understanding My Data, Myself: Supporting Self-reflection with Ubicomp Technologies. In *Proceedings of the 13th International Conference on Ubiquitous Computing* (pp. 405–414). New York, NY, USA: ACM. <http://doi.org/10.1145/2030112.2030166>

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006). Fish’N’Steps: Encouraging Physical Activity with an Interactive Computer Game. In *Proceedings of the 8th International Conference on Ubiquitous Computing* (pp. 261–278). Berlin, Heidelberg: Springer-Verlag. http://doi.org/10.1007/11853565_16

MacLeod, H., Tang, A., & Carpendale, S. (2013). Personal informatics in chronic illness management (pp. 149–156). Canadian Information Processing Society. Retrieved from <http://dl.acm.org/citation.cfm?id=2532129.2532155>

Mattila, E., Parkka, J., Hermersdorf, M., Kaasinen, J., Vainio, J., Samposalo, K., ... Korhonen, I. (2008). Mobile Diary for Wellness Management-Results on Usage and Usability in Two User Studies. *IEEE Transactions on Information Technology in Biomedicine*, 12(4), 501–512. <http://doi.org/10.1109/TITB.2007.908237>

Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & Health*, 26(11), 1479–1498. <http://doi.org/10.1080/08870446.2010.540664>

miCoach Laufen & Training. (2015). Retrieved April 25, 2015, from <https://play.google.com/store/apps/details?id=com.adidas.micoach&hl=de>

Mintz, D., Fitz-Simons, T., & Wayland, M. (1997). Tracking Air Quality Trends with SAS/GRAPH (pp. 807–812). Presented at the Proceedings of the 22nd Annual SAS User Group International Conference (SUGI97).

Misfit Flash | Sporty Fitness + Sleep Monitor. (2015). Retrieved February 4, 2015, from <http://misfit.com/products/flash>

Moov - 7 Minute+ Workout Coach. (2015). Retrieved April 25, 2015, from <https://itunes.apple.com/us/app/7-minute+-workout-coach-from/id951389684?ls=1&mt=8>

Moov 7 Minutes+ Workout. (2015). Retrieved April 25, 2015, from <http://training.moov.cc/>

Moov Cardio Boxing Wearable Coach. (2015). Retrieved April 25, 2015, from <https://itunes.apple.com/us/app/moov-boxing-cardio-punch/id914302622?mt=8>

Moov Cardio Punch. (2015). Retrieved April 25, 2015, from <http://boxing.moov.cc/>

Moov Swim. (2015). Retrieved April 25, 2015, from <http://swim.moov.cc/>

Moov Swim Wearable Coach. (2015). Retrieved April 25, 2015, from <https://itunes.apple.com/us/app/moov-swim-coaching-moov-wearable/id921776726?mt=8>

Moov: The world's most advanced fitness device. (2015). Retrieved February 20, 2015, from <http://welcome.moov.cc/>

Munson, S. (2012). Mindfulness, Reflection, and Persuasion in Personal Informatics.

Munson, S. A., & Consolvo, S. (2012). Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. In *2012 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)* (pp. 25–32).

Munzner, T. (2009). A Nested Model for Visualization Design and Validation. *IEEE Transactions on Visualization and Computer Graphics*, 15(6), 921–928. <http://doi.org/10.1109/TVCG.2009.111>

Munzner, T. (2015). *Visualization Analysis and Design*. CRC Press.

Murray, S. (2013). *Interactive Data Visualization for the Web*. O'Reilly Media.

Neil, T. (2014). *Mobile Design Pattern Gallery: UI Patterns for Smartphone Apps* (Second Edition). O'Reilly Media.

Nielsen, J., & Landauer, T. K. (1993). A Mathematical Model of the Finding of Usability Problems. In *Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems* (pp. 206–213). New York, NY, USA: ACM. <http://doi.org/10.1145/169059.169166>

Nike Fuelband. (2015). Retrieved October 28, 2014, from http://www.nike.com/de/de_de/c/nikeplus-fuelband

Ordinal Scale mbostock/d3. (n.d.). Retrieved April 12, 2015, from <https://github.com/mbostock/d3>

Packer, H. S., Buzogany, G., Smith, D. A., Dragan, L., Van Kleek, M., & Shadbolt, N. R. (2014). The Editable Self: A Workbench for Personal Activity Data. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (pp. 2185–2190). New York, NY, USA: ACM. <http://doi.org/10.1145/2559206.2581283>

Pansiot, J., King, R. C., McIlwraith, D. G., Lo, B., & Yang, G.-Z. (2008). ClimBSN: Climber performance monitoring with BSN. In *5th International Summer School and Symposium on Medical Devices and Biosensors, 2008. ISSS-MDBS 2008* (pp. 33–36). <http://doi.org/10.1109/ISSMDBS.2008.4575009>

Pavel, D., Trossen, D., Holweg, M., & Callaghan, V. (2013). Lifestyle stories: Correlating user information through a story-inspired paradigm. In *2013 7th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)* (pp. 412–415).

Peak Page - Basis. (2015). Retrieved April 26, 2015, from <https://www.mybasis.com/>

Polar Loop und V800. (2015). Retrieved February 12, 2015, from <http://www.polar.com/at-de/produkte>

Quaine, F., Martin, L., & Blanchi, J. P. (1997). Effect of a leg movement on the organisation of the forces at the holds in a climbing position 3-D kinetic analysis. *Human Movement Science*, 16(2–3), 337–346. [http://doi.org/10.1016/S0167-9457\(96\)00060-7](http://doi.org/10.1016/S0167-9457(96)00060-7)

Ramirez, E. (2015). Wrist Wearables: How Many Are There? Retrieved from <http://quantifiedself.com/2014/09/wrist-wearables-now/>

Runtastic Apps. (2015). Retrieved November 13, 2014, from <https://www.runtastic.com/de/apps>

Runtastic Orbit - Aktivitäts, Fitness & Schlaf Tracker. (2015). Retrieved February 4, 2015, from <https://www.runtastic.com/shop/de/runtastic-orbit>

Schmid, T., Shea, R., Friedman, J., & Srivastava, M. B. (2007). Movement Analysis in Rock-Climbers. In *Proceedings of the 6th International Conference on Information Processing in Sensor Networks* (pp. 567–568). New York, NY, USA: ACM. <http://doi.org/10.1145/1236360.1236443>

Sedlmair, M., Meyer, M., & Munzner, T. (2012). Design Study Methodology: Reflections from the Trenches and the Stacks. *IEEE Transactions on Visualization and Computer Graphics*, 18(12), 2431–2440. <http://doi.org/10.1109/TVCG.2012.213>

Severity Ratings for Usability Problems: Article by Jakob Nielsen. (2015). Retrieved April 14, 2015, from <http://www.nngroup.com/articles/how-to-rate-the-severity-of-usability-problems/>

Shneiderman, B. (1996). The eyes have it: a task by data type taxonomy for information visualizations. In *IEEE Symposium on Visual Languages, 1996. Proceedings* (pp. 336–343). IEEE Comput. Soc. Press. <http://doi.org/10.1109/VL.1996.545307>

Simple Climbing Log. (2015). Retrieved November 4, 2014, from <https://play.google.com/store/apps/details?id=uk.me.eddies.apps.simpleclimbinglog>

Soegaard, M. (2015). Gestalt principles of form perception. Retrieved April 23, 2015, from /encyclopedia/gestalt_principles_of_form_perception.html

Spence, R. (2007). *Information Visualization: Design for Interaction* (2nd Edition). Upper Saddle River, NJ, USA: Prentice-Hall, Inc.

Ståhl, A., Höök, K., Svensson, M., Taylor, A. S., & Combetto, M. (2009). Experiencing the Affective Diary. *Personal and Ubiquitous Computing*, 13(5), 365–378. <http://doi.org/10.1007/s00779-008-0202-7>

Testa, M., Martin, L., & Debû, B. (1999). Effects of the type of holds and movement amplitude on postural control associated with a climbing task. *Gait & Posture*, 9(1), 57–64. [http://doi.org/10.1016/S0966-6362\(98\)00036-8](http://doi.org/10.1016/S0966-6362(98)00036-8)

Tory, M. (2014). User Studies in Visualization: A Reflection on Methods. In W. Huang (Ed.), *Handbook of Human Centric Visualization* (pp. 411–426). New York: Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4614-7485-2_16

Tudor-Locke, C. (2002). Taking Steps toward Increased Physical Activity: Using Pedometers To Measure and Motivate, *President's Council on Physical Fitness and Sports Research Digest*(3), 1–8.

Tufte, E. R. (2006). *Beautiful Evidence* (1st Edition edition). Cheshire, Conn: Graphics Pr.

UP - Jawbone UP24. (2015). Retrieved November 4, 2014, from <https://jawbone.com/up>

Van Someren, M. W., Barnard, Y. F., Sandberg, J. A., & others. (1994). *The think aloud method: A practical guide to modelling cognitive processes* (Vol. 2). Academic Press London. Retrieved from http://echo.iat.sfu.ca/library/vanSomeren_94_think_aloud_method.pdf

van Welie, Martijn. (2015). Interaction Design Pattern Library - Form. Retrieved April 11, 2015, from <http://www.welie.com/patterns/showPattern.php?patternID=forms>

Velazco, C. (2015). Social Fitness Tracker Endomondo Hits 10 Million Users, Tracks 250K Workouts Each Day. Retrieved February 12, 2015, from <http://social.techcrunch.com/2012/06/27/social-fitness-tracker-endomondo-hits-10-million-users-tracks-250k-workouts-each-day/>

vívofit 2 - Fitnesstracker | GARMIN | Deutschland. (2015). Retrieved February 5, 2015, from <http://sites.garmin.com/de-DE/vivo/vivofit/>

White, D. J., & Olsen, P. D. (2010). A time motion analysis of bouldering style competitive rock climbing. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, 24(5), 1356–1360. <http://doi.org/10.1519/JSC.0b013e3181cf75bd>

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Appendix

A. Guideline Contextual Semi-Structured Interview

Herzlich Willkommen und danke, dass du dir Zeit genommen hast für ein kurzes Interview!

Ich schreibe derzeit meine Diplomarbeit zum Thema Sport Visualisierung im Bereich Klettern. Ich möchte ein Tool entwickeln, mit dem Kletterer ihre Daten analysieren können. Das Hauptaugenmerk ist es, bestehende Daten von solchen Armbändern zu nehmen und diese so darzustellen, dass ein Kletterer sich in seinem Trainingslevel verbessern kann. Es soll einerseits ein Tool dafür geben und andererseits eine mobile Applikation am Smartphone entstehen, die eine Art Tourenbuch darstellt. Diese beiden Programme sollen sich auch ergänzen und so ein einheitliches System für Kletterer darstellen, gleich ob im Bereich des Indoor- oder Outdoorkletterns.

Dazu arbeite ich mit den ForscherInnen des Projektes ClimbAX aus Newcastle zusammen. Diese ForscherInnen haben ein solches Armband für den Klettersport entwickelt. Leider gibt es dieses Armband noch nicht am Markt zu kaufen. Die Armbänder legt der/die SportlerIn während des Kletterns an. Diese beiden Bewegungssensoren, die in diesen Armbändern verbaut sind, tracken die Kletterbewegungen mit. Die ForscherInnen haben um die Qualität der Bewegungen darzustellen, Parameter definiert: Kontrolle, Stärke, Stabilität und Zeit. Ein Algorithmus erkennt, ob der/die SportlerIn gerade klettert oder zum Beispiel herumgeht in der Kletterhalle, um die nächste Route zu sichten. Zusätzlich zu den 4 Parametern wird der Name der Kletterroute und die Zeit, wie lange auf der Route geklettert wurde, gespeichert. Außerdem werden die Moves (Bewegung zu den Griffen) aufgezeichnet.

Ziel dieses Interviews ist es, herauszufinden, welche Anforderungen von Kletterern an diese Systeme gestellt werden. Außerdem erhoffe ich mir, ein kurzes Feedback zu den bestehenden Skizzen der Datenauswertung von ClimbAX zu bekommen.

Kurz zum Ablauf: Ich werde dir jetzt noch ein paar Fragen zu deiner Person stellen und dann beginnt die Befragung. Dazu habe ich noch ein Bild

mitgebracht, das ich dir dann zeigen werde. Ich hoffe, dass eine Diskussion zustande kommt und ich wichtige Erkenntnisse für meine Arbeit gewinne.

In dieser Zeit des Interviews werde ich Audioaufnahmen machen, die aber nicht an Dritte weitergegeben werden. Diese Aufnahmen werden nur im Zuge der Diplomarbeit erstellten Forschungsarbeit verwendet.

Name:

Alter:

Klettern seit:

Wie schätzt du dein Können im Klettern ein?

_____Anfänger _____Fortgeschritten _____Profi

Andere Hobbys:

Beruf:

Smartphone oder Tablet: Ja/Nein

Applikation für das Klettern: Ja/Nein - > Wenn ja, welches Tool?

- Fährst du ein Tourenbuch oder eine Aufzeichnung darüber, welche Routen du geklettert bist? Zum Beispiel digital über eine Applikation oder Dokument oder analog in einem Buch? Wenn ja: Welche Informationen möchtest du zu einer Route speichern und aufzeichnen? (zum Beispiel - Bilder, Grad, Datum und Uhrzeit, Wetter (outdoor), körperliche Verfassung)
- Hast du Erfahrungen mit Applikationen wie Runtastic, Endomondo, Strava oder speziellen Tools oder Applikationen im Bereich Klettern?
- Verwendest du Wearable Devices wie Garmin Forerunner, Fitbit, Misfit oder ähnliche Systeme?
- Bitte sieh dir dieses Bild an und erkläre mir was du hier siehst und was diese Diagramme bedeuten könnten.
- Kannst du dir vorstellen, ein solches Armband beim Klettern zu tragen und diese Daten dann auf eine Plattform zu importieren um sie zu sammeln und zu analysieren?
- Wie würdest du vorgehen, wenn du Daten gesammelt hast mit dem Armband und dann deine Daten anschauen und analysieren möchtest? Auf welcher Plattform möchtest du die Analyse durchführen, am Smartphone, Tablet oder Desktop-Computer bzw. Laptop?
- Welche Parameter bzw. Fähigkeiten sind für dich beim Klettern wichtig?

- Was soll alles dargestellt werden, um es für dich so leicht wie möglich zu machen, die gesammelten Daten zu analysieren zu können?
- Kennst du diese Art von Visualisierungen (Grafik herzeigen – verschiedene Arten von Visualisierungen sind hier abgebildet)? Welche würdest du verwenden, um die von dir genannten Informationen darzustellen?
- Möchtest du dich mit anderen vergleichen können oder reicht es für dich aus, die einzelnen Klettertage aufzuzeichnen?
- Welche Ziele setzt du dir beim Klettern? Und wie erkennst du, dass du deine Ziele erreicht hast?
- Wie soll dir das von mir entwickelte Tool dabei helfen, dein Können zu steigern und deine Ziele zu erreichen? Zum Beispiel in Form von hilfreichen Tipps, motivierenden Worten, Hinweisen zu besserer Klettertechnik,....
- Wie motivierst du dich? Bzw. Was motiviert dich beim Klettern?

B. Guideline Expert Review

Ich schreibe derzeit meine Diplomarbeit zum Thema Sport Visualisierung im Bereich Klettern. Ich möchte ein Tool entwickeln, wo Kletterer ihre Daten analysieren können. Das Hauptaugenmerk ist es, bestehende Daten von solchen Armbändern zu nehmen und diese so darzustellen, dass ein Kletterer sich in seinem Trainingslevel verbessern kann. Es soll einerseits ein Tool dafür geben und andererseits eine mobile Applikation am Smartphone entstehen, die eine Art Tourenbuch darstellt. Diese beiden Programme sollen sich auch ergänzen und so ein einheitliches System für Kletterer darstellen, gleich ob im Bereich des Indoor- oder Outdoorkletterns.

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Ziel dieses Interviews ist es, herauszufinden, ob das von mir entwickelte Konzept für diese Problembeschreibung funktioniert in Bezug auf die Darstellung der Daten und Auswahl der Visualisierungstechniken.

Zuerst werde ich dir die Prototypen zeigen und dann stelle ich dir zwei Situationen vor, in die du dich hineinversetzen sollst.

Name & Domain-Experte in:

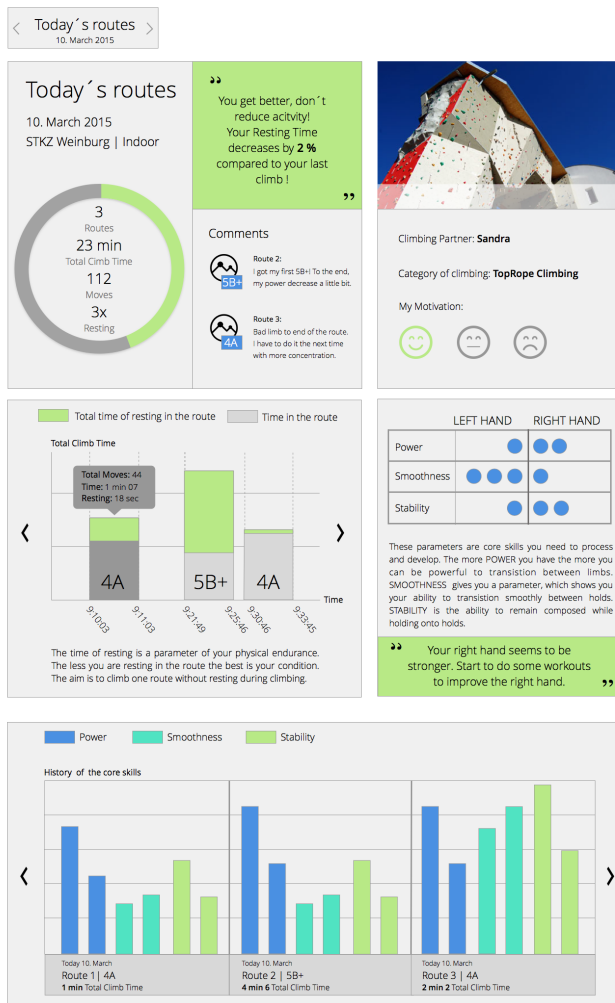
- Bitte sieh dir die mitgebrachten Papier-Prototypen an und sag mir, was du hier siehst?

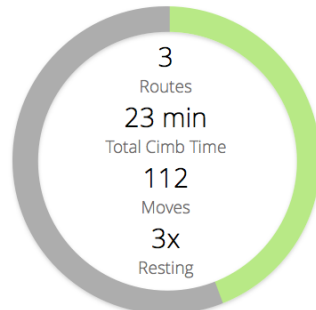
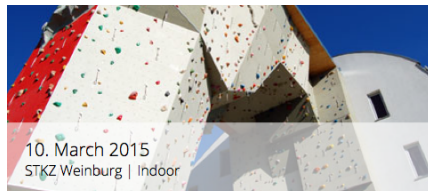
Szenario 1: Nach dem Klettern musst du wie jedes Mal auf deinen Kletterkollegen warten. In dieser Zeit willst du den heutigen Klettertag auf deinem Smartphone analysieren. Seit der Markteinführung der Wearable Devices von ClimbAX verwendest du beim Klettern diese Armbänder. Zur schnellen Analyse der Daten öffnest du die mobile Webseite. Du analysierst deinen Kletterstatus und auch die einzelnen Routen genau. Weiters siehst du dir die Balance zwischen linker und rechter Hand genauer an.

Szenario 2: Nach der Analyse fällt dir ein Parameter ins Auge, den du dann zuhause auf deinem Laptop genauer analysieren möchtest. Der Verlauf der Parameter Power Control Stability interessiert dich besonders, da du den Verlauf über eine längere Zeit verfolgen willst. Bei den letzten Analysen ist dir aufgefallen, dass die rechte Hand schwächer ist als die linke. Mit gezielten Übungen in den letzten Wochen hast du versucht diese Disbalancen auszugleichen.

Bei der Analyse der Screens bitte ich dich, folgende Bereiche zu analysieren und Feedback zu geben:

- Wording
- Konsistenz der Elemente
- Verwendung der Visualisierungstechniken
- Farbeinsatz und Design von Feedback
- Interaktion
- Navigation
- Layout





“ You get better, don’t reduce activity!
Your Resting Time decreases by 2 %
compared to your last climb ! ”

< Today’s routes >
10. March 2015

Add your information to the climb of today:

Add Climbing Partner: **Sandra**

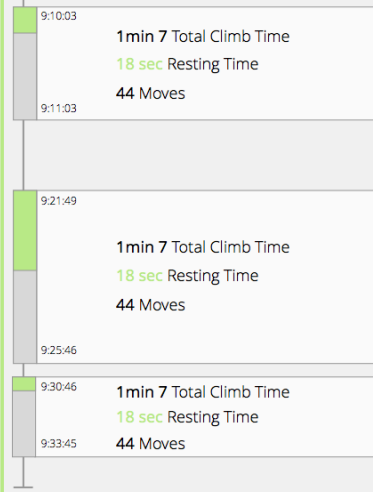
Category of Climb: **Top Rope Climbing**

My Motivation:

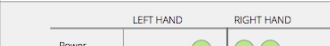


Your routes of today:

Add Comment: + Add Grade: +



Balance between left and right hand: v



“ You get better, don’t reduce activity!
Your Resting Time decreases by 2 %
compared to your last climb ! ”

< Today’s routes >
10. March 2015

Add your information to the climb of today:

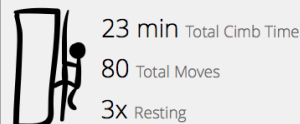
Add Climbing Partner: **Sandra**

Add Climbing Partner: **TopRope Climbing**

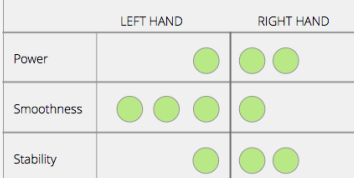
My Motivation:



Your routes of today: v

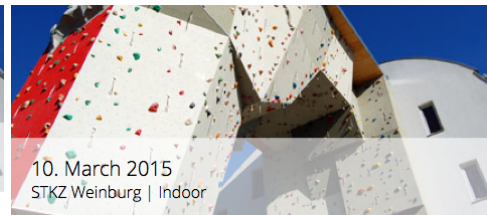
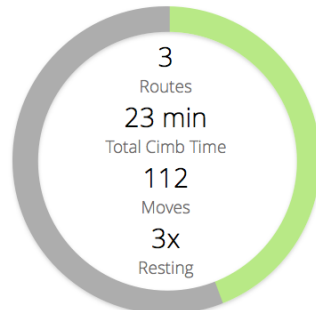
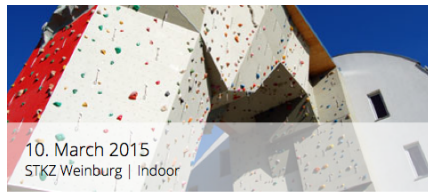


Today’s balance of right and left hand ^



These parameters are core skills you need to process and develop. The more POWER you have the more you can be powerful to transition between limbs. ZITTERN gives you a parameter, which shows you your ability to transition smoothly between holds. STABILITY is the ability to remain composed while holding onto holds.

“ Train your left hand to become more powerful between limbs. ”



“ You get better, don't reduce activity!
Your Resting Time decreases by 2 %
compared to your last climb ! ”

< Today's routes >
10. March 2015

Add your information to the climb of today:

Add Climbing Partner: **Sandra**

Category of Climb: **Top Rope Climbing**

My Motivation:



Your routes of today:

Add Comment: ⊕

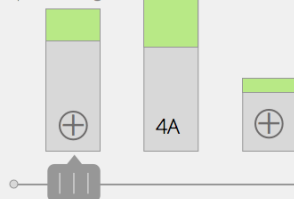


Route 2:
I got my first 5B+! To the
end, my power decrease a
little bit.

more Comments

Route 1 | 9:10:03 - 9:11:03 44 Moves
1min 7 Total Climb Time 18 sec Total Resting Time

Tap to add a grade



Total Resting Time Time in the Route

“ You get better, don't reduce activity!
Your Resting Time decreases by 2 %
compared to your last climb ! ”

< Today's routes >
10. March 2015

Add your information to the climb of today:

Add Climbing Partner: **Sandra**

Category of Climb: **Top Rope Climbing**

My Motivation:



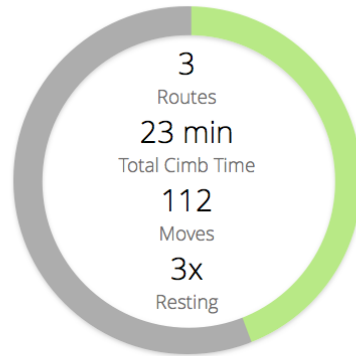
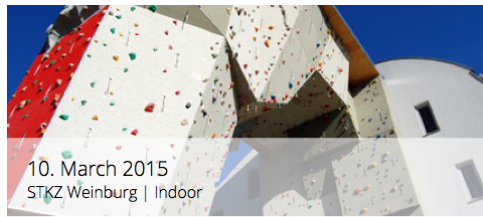
Your routes of today:



23 min Total Climb Time
80 Total Moves
3X Resting

Balance between left and right hand:

	LEFT HAND	RIGHT HAND
Power	●	● ●
Zittern	● ● ●	●
Stability	●	● ●



“ You get better, don´t reduce acitivity!
Your Resting Time decreases by 2 %
compared to your last climb ! ”

< Today´s routes >
10. March 2015

Add your information to the climb of today:

Add Climbing Partner: ⊕

Add Category ▼

My Motivation:



Your routes of today: ▼



23 min Total Climb Time

80 Total Moves

3X Resting

Balance between left and right hand: ▼

	LEFT HAND	RIGHT HAND
Power	●	● ●
Zittern	● ● ●	●
Stabilität	●	● ●

C. Guideline Usability Study

Willkommen (5 min)

Mein Name ist Christina und ich werde dich durch diesen Test begleiten. Bevor wir diesen Test durchführen, werde ich dir nähere Informationen zum Ablauf vorlesen. Das Vorlesen ist deshalb wichtig, da ich allen Testpersonen die gleichen Informationen übermitteln möchte.

Bei diesem Test wird eine mobile Webseite und eine Webanwendung im Bereich Klettern auf ihre Nutzbarkeit getestet. Nicht du als Person wirst getestet, sondern die Anwendung. Bitte sei ehrlich und habe keine Angst, dass du durch eine Kritik mich als Person verletzt. Ich freue mich auf deine genaue Einschätzung zur getesteten Applikation.

Zu Beginn stelle ich dir ein paar Fragen zur deiner Person, deinem Lebensumfeld und deiner Erfahrung mit Sportanwendungen. Danach zeige ich dir die zwei Prototypen. Dazu habe ich zwei Situationen erstellt, in die du dich hineinversetzten sollst. Du bekommst kurze Aufgaben von mir, die du durcharbeiten sollst. Nach dem Lösen der Aufgaben bitte ich dich, noch ein paar offene Fragen zu beantworten.

Ich werde dich während der nächsten Zeit genau beobachten und werde dazu Notizen machen. Zusätzlich wird von diesem Test ein Video aufgenommen. Diese Videos helfen uns bei der Testanalyse und der Verbesserung der Fehler in der Applikation. Diese Videoaufnahmen werden nicht außerhalb dieses Projektes verwendet.

Treten während des Tests Fragen auf, lass es mich bitte sofort wissen. Für eine bessere Analyse des Tests bitte ich dich, bei den Aufgaben deine Gedanken und jeden Schritt, den du tun wirst, laut auszusprechen.

Hast du jetzt noch Fragen?

[Kamera starten]

Wir beginnen jetzt mit den Fragen zu deiner Person:

Name:

Geschlecht:

Alter:

Beruf:

Klettern seit:

Wie schätzt du dein Können im Klettern ein?

Anfänger

Fortgeschritten

Profi

Besitzt du ein Smartphone oder Tablet oder beides?

☐ Tablet

☐ Smartphone

☐ Beides

Führst du ein Tourenbuch für deine Kletterrouten?

☐ Ja, Welches _____

☐ Nein

Hast du Erfahrungen mit Sport-Applikationen?

Danke für deine Informationen. Beginnen wir jetzt mit den Aufgaben auf der mobilen Anwendung. Bitte sprich alle Gedankengänge laut aus, während du die Aufgaben löst.

Aufgaben & Szenario (15min)

Kennenlernen der mobilen Applikation (3 min)

Du befindest dich jetzt auf der mobilen Webseite und siehst den heutigen Klettertag. Sieh dich um und scrolle durch die Webseite, um dir einen ersten Eindruck zu machen.

Was ist dein erster Eindruck

Danke für deine Einschätzung. Starten wir jetzt mit den Aufgaben. Ich bitte dich, bei den Aufgaben deine Gedanken und jeden Schritt, den du tun wirst, laut auszusprechen.

Mobile Version

Bitte stelle dir folgende Situation vor:

Nach dem Klettern musst du wie jedes Mal auf deinen Kletterkollegen warten. In dieser Zeit willst du den heutigen Klettertag auf deinem Smartphone analysieren.

Seit der Markteinführung der Wearable Devices von ClimbAX verwendest du die Armbänder zum Klettern. Die Daten werden über Bluetooth von deinen Armbändern auf das Handy übertragen.

Aufgabe 1 – Kletterstatus:

Sieh dir deinen heutigen Kletterstatus an.

Bitte erkläre mir, wie dein Klettertag heute so war.

- War eine Hilfestellung notwendig, um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?

Notizen:

Aufgabe 2 – Eingaben von Daten:

Du gibst jetzt den Namen deines Kletterpartners ein und wählst eine Kategorie und einen Typ aus. Noch dazu wählst du deine heutige Motivation beim Klettern aus und speicherst deine Eingaben ab. **Bitte zeig mir, wie du dies machen würdest.**

- War eine Hilfestellung notwendig, um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen??
- Waren mehrere Versuche notwendig

Notizen:

Aufgabe 3 – Routen:

Du siehst dir die Routen jetzt genauer an. **Bitte erkläre mir wie lange du bei der zweiten Route geklettert bist und wie viel du gerastet hast?**

Bitte erkläre mir auch, wie du zu der ersten Route einen Schwierigkeitsgrad und einen Kommentar hinzufügen würdest.

Notizen:

- War eine Hilfestellung notwendig um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?
- Waren mehrere Versuche notwendig?

Notizen:

Aufgabe 4 – Balance Rechte & Linke Hand:

Weiters interessiert dich die Balance zwischen deiner linken & rechten Hand. **Navigiere zu der Übersicht und öffne diese und erkläre mir, was du hier siehst.**

- War eine Hilfestellung notwendig, um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?

Notizen:

So der erste Teil wäre geschafft. Vielen Dank für deine Mitarbeit. Jetzt wechseln wir auf die Webseite.

Webversion

Bitte stelle dir jetzt folgende Situation vor:

Nach der Analyse fällt dir der Parameter „Power“ ins Auge, den du zuhause auf einem Laptop genauer analysieren möchtest. Zuhause angekommen, öffnest du sofort die Webseite und startest mit der Analyse deiner Kletterdaten.

Aufgabe 1 – Routenübersicht:

Du siehst dir den Verlauf der Routen an.

Bitte erkläre mir diese Grafik.

- War eine Hilfestellung notwendig, um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?

Notizen:

Aufgabe 2 – Balance Übersicht:

Dich interessiert nun der Verlauf der Parameter zur Analyse der Balance von rechter und linker Hand auf deinen gesamten Klettertag. Dazu wechselst du die Ansicht, um einen Überblick über die Parameter zu erhalten.

Bitte erkläre mir, was du siehst.

- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?

Notizen:

Aufgabe 3 – Balance Rechte & Linke Hand

Da dir bei der dritten und letzten Route schon ein wenig die Kraft ausgegangen ist, interessierst dich besonders für die dritte Route die Balance zwischen deiner linken und rechten Hand. Du navigierst zu der Information.

Bitte sag mir, ob eine Balance zwischen rechter und linker Hand im Bereich Power bei der zweiten Route gegeben ist. Um dies herauszufinden blende die einzelnen Parameter ein und aus.

- War eine Hilfestellung notwendig, um die Aufgabe zu lösen?
- Traten falsche Annahmen auf?
- Unmutsäußerungen der Testpersonen?

Notizen:

Aufgabe 4 – Overview Grafik:

Da du in letzter Zeit versucht hast, mehr zu trainieren, schaust du dir über ein Monat deine Klettertage an.

Bitte erkläre mir, wie der Verlauf deiner Klettertage war in Bezug auf die Anzahl der Klettertage und Anzahl der Routen.

Zeig mir, wie du die Ansicht auf eine Jahresansicht wechseln würdest.

Du blendest die linke Hand beim Parameter Power aus. Bitte zeig mir, wie du hier vorgehst.

Bitte erkläre mir jetzt den Verlauf des Parameters Power.

- Traten falsche Annahmen auf?
- War eine Hilfestellung notwendig um die Aufgabe zu lösen?
- Unmutsäußerungen der Testpersonen?

Notizen:

Danke, du hast alle Aufgaben durchgearbeitet. Jetzt werde ich dir noch ein paar Fragen stellen.

Offene Fragen zur Mobilen Webseite (5min)

- Hast du dich schnell in der Applikation am Handy zurechtgefunden?
- Wie schwierig war es für dich die Aufgaben zu lösen?
- Waren die Darstellungen der Daten einfach zu lesen für dich?
- Was hat dir gefallen und was hat dir nicht gefallen?
- Fehlen dir bei der Mobilen Seite Informationen, um deinen Klettertag zu analysieren bzw. fehlt dir etwas anderes?
- Was würdest du verbessern?
-

Offene Fragen zu Webanwendung (5min)

- Hast du dich schnell auf der Webseite zurechtgefunden?
- Wie schwierig war es für dich, die Aufgaben zu lösen?
- Waren die Darstellungen der Daten einfach zu lesen für dich?
- Was hat dir gefallen und was hat dir nicht gefallen?
- Fehlen dir Informationen, um deinen Klettertag zu analysieren bzw. fehlt dir etwas anderes?
- Was würdest du verbessern?
- Würdest du, wenn es dieses System gibt, es in deinem Klettertraining integrieren?
- Welche Version würdest du lieber benutzen, die am Smartphone oder am PC? Und erkläre mir warum?
- Gibt es sonst noch Feedback, Dinge, die dir aufgefallen sind oder Verbesserungen?

[Kamera stoppen]

D. Demo Visualization of ClimbAX

