HAW HAMBURG

MASTERTHESIS
Nora Berg

Ethical Reflections on Quantified Self Devices and their Effects on Humans

FAKULTÄT TECHNIK UND INFORMATIK
Department Informatik

Faculty of Computer Science and Engineering
Department Computer Science

HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN HAMBURG
Hamburg University of Applied Sciences

Nora Berg

Ethical Reflections on Quantified Self Devices and their Effects on Humans

Masterarbeit eingereicht im Rahmen der Masterprüfung
im Studiengang Master of Science Informatik
am Department Informatik
der Fakultät Technik und Informatik
der Hochschule für Angewandte Wissenschaften Hamburg

Betreuender Prüfer: Prof. Dr. Kai von Luck
Zweitgutachter: Dr. Susanne Draheim

Eingereicht am: 29. August 2019

Nora Berg

Thema der Arbeit

Ethical Reflections on Quantified Self Devices and their Effects on Humans

Stichworte

Ethik, Quantified-Self, Mensch-Computer-Interaktion, Critical Design, Fitness-Tracker, Transparenz, Privatspäre, Autonomie, Verantwortung

Kurzzusammenfassung

In dieser Arbeit werden die ethischen Konsequenzen von Quantified Self Technologie evaluiert. Dabei stehen hauptsächlich Effekte auf Nutzer und Gesellschaft im Fokus. Gegenwärtige Anreize zur Selbstoptimierung, konstantes Aufzeichnen physiologischer Daten und Feedback an die Nutzer erschaffen Geräte, die moralisch fragwürdig sind, da die positiven Effekte mehrheitlich in best-case Szenarien gefunden werden konnten. Darüberhinaus haben Quantified-Self-Geräte das Potenzial Nutzern Schaden zuzufügen. Anstelle der gegenwärtigen Annahmen, wie ein Quantified-Self-Gerät funktionieren soll, werden in dieser Arbeit neue Vorschläge für Richtlinien erarbeitet. Diese berücksichtigen die jeweiligen ethischen Werte und Wissen aus der Psychologie über die Wirkungsweise von Feedback und Verhaltensänderung. Die Richtlinien beabsichtigen unter anderem, ethische Werte wie Autonomie, Privatsphäre und Transparenz zu erhalten. Das Ziel der Richtlinien ist Wege aufzuzeigen, welche die individuelle menschliche Weiterentwicklung und Zufriedenheit unterstützen Die Argumentation wird anhand eines Critical-Design-Konzeptes eines intelligenten Kleides und dessen Userstory entwickickelt. Erkenntnisse aus Soziologie, Psychologie und Ethik werden genutzt um Designkonzepte, Annahmen und mögliche Auswirkungen auf Nutzer zu analysieren.

Nora Berg

Title of Thesis

Ethical Reflections on Quantified Self Devices and their Effects on Humans

Keywords

Ethics, Quantified Self, Human Computer Interaction, Critical Design, Fitness tracker, Transparency, Privacy, Autonomy, Responsibility

Abstract

This thesis reflects ethical consequences of quantified self devices. Thereby, it focuses mainly on the effects on users and society. Contemporary incentives for self-optimization, constant tracking of physiological data, and feedback to users create devices which are morally questionable, since positive effects could mainly be found in certain best case scenarios. Furthermore, quantified self devices have the capability to even harm users. Instead of the contemporary design assumptions, new baselines are elaborated, which aim to maintain the respective ethical values and psychological knowledge about feedback and behavior change. These baselines intend to maintain values as autonomy, privacy, transparency, and others to find ways which support individual human growth and happiness. The argumentation unfolds alongside a critical design concept of a smart dress and its respective userstory. Insights from sociology, psychology and ethics are used to evaluate design concepts, assumptions, and possible impact on users.

Contents

1 Introduction

Quantified self describes the action of people to track and optimize certain aspects of their lives. In the last years, this tendency spread to smartphones and to explicit quantified self devices. Almost everything can be tracked, how users spend their time, what they eat, how well they sleep, which emotions they have, how much exercise they do, how much money they spend, how often they meditate, and more. Contemporary quantified self devices are often in form of wrist watches and offer information about the physical body. They often work in combination with smartphone applications, which offer additional tracking support for food intake or tools for analysis. The constant monitoring and analysis of human features effect users. The goal is that users change to a more healthy, more fit lifestyle. This thesis focuses on consequences of constant (self-)monitoring, analysis, and mirroring of users. Thereby, mirroring describes the reflection of tracked and evaluated data as a kind of quantified persona. We want to know, which effects are elicited in users and whether the promised advantages are attained. Further, we analyze how well the effects of usage work out for users. To achieve this, we follow the critical design approach and conceptualize an intelligent dress with a corresponding user story. Therewith, we gain insight how human life would look like, if these devices were ubiquitous and well integrated in the environment. We analyze user story and dress in reference to several psychological and sociological theories on the functioning of humans and societies to extract risk and advantages. In several ethical reflections we analyze the dress and its effects under certain moral values which all influence humans happiness and flourishing. Therein, we critic self-optimization tendencies in societies and how they work out over the devices. Eventually, we gain several insights how devices would need to be developed, to actually support humans. For this, developers and producers would need a fundamentally different attitude towards their products and users. The contact to individual users would need to be much closer, and the devices would need to base on different user stories than self-optimization.

This thesis aims to find a standpoint towards the responsibility of computer scientists and developers towards their technological advancements. A further goal was to promote

a reflective distance to our own daily work. Therefore, this thesis includes opinions and intents to start a discussion about a possible different ethical code for technological development. For the interdisciplinary part, i.e. the sociological, psychological and ethical background, a lot of extra-curricular reading was done, but this thesis was written on the basis of academical education in computer science.

This work is structured in eight chapters. The introductory part includes an overview of the related work (Chapter 2), as well as an overview about the workings of quantified self, quantified self technology, and users of quantified self devices (Chapter 3). Thereafter, follows the chapter about the smart dress as critical design concept (Chapter 4). Next to concept and user story, this chapter includes more details about possible implementations of such a dress and a proof of concept project. The next part concerns effects of quantified self devices on users (Chapter 5). Herein, we summarize sociological and psychological concepts and analyze how they work out in the user story of our intelligent dress. In Chapter 6, we analyze the results of the previous chapters under ethical standpoints. We examine which values are affected to what extend and search for possibilities to create similar devices without transgressing those values. Finally, we conclude and give an outlook for future research in Chapter 7 and Chapter 8.

2 Related Work

Research on effects of quantified self technology spreads over several disciplines. The research for this work includes literature from computer science, sociology, art and design, ethics, and psychology. In this section we summarize the most influential papers for the reflection on quantified self devices for this thesis.

The technology of quantified self devices as used in this thesis is primarily developed in economical settings. Nevertheless, certain technological enhanced materials inspired this thesis. In “Musicking the body electric" [18] textiles were advanced with sensors and communication abilities to create new forms for musicians to play together. Herein, the feedback mechanisms were of interest because they transmit information directly to the skin and this is a feature our dress also includes. Another, more commercial project, ist “THE UNSEEN” [12], which creates colors, pieces, clothes, and accessories which change color due to certain context variables. They make invisible details visible, for example by showing structures of brain activism, hair color which changes due to temperature, and created a jacket which changed color due to pollution in the air. These things are not digital but base on material science to create such effects.

Hertzian Tales [28] by Dunne uses product design to show alternative futures of technological development. For this, it establishes the term *critical design* to question the usage and consequences of electronic objects. It shows how users are domesticated by user models and narratives which offer only limited ways of utilization. The narrative of utilization itself can be critical. For example. the “homeless vehicle” is created to support homeless people in their lifestyle. Users of those vehicles would be supported, i.e. “domesticated” to stay homeless rather, than they would be supported to find an apartment. Electronic objects offer an extension to the analog world, and this is critically examined. Dunne shows how in art, experience of software or radio signals create a new dimension of reality, which is invisible and untouchable, but still influences the analog real world. In this thesis we examine how the users world is influenced by smart textile objects, and which stories in the users lives emerge. Instead of letting the mind of the

viewer do this work, as the product designs in *Hertzian Tales* would do, we examine concrete consequences for users and the environment they live in. Dunne further introduces the extension to the so called *hertzian space*. Herein, he questions a set of yet undefined or unspoken social rules. He transgresses them purposely, and uses it as pointed exaggerations to show alternative versions of reality. Those designs ask questions over the consequences of usage of everyday electronic objects. These questions are interesting for this thesis because the questions deepen our understanding of concepts of how emotional comfort can be achieved, on the other hand, broaden the horizon of the worst possible consequences. It also hints which values are important to people in everyday life (in conjunction with electronic objects), because they can more easy recognized, if they are broken. The critical design approach offers insight over these values, by breaking them in a safe way. Inspired by this approach we conceptualize an intelligent dress and create a proof-of-concept piece, an intelligent sleeve. The goal is to conclude a narrative around its usage and to extract key characteristics of their impact on users and environment. In the ethical part of this thesis we evaluate transgressions of still vaguely defined social rules and moral standpoints on quantified self devices

Mark Weisers *Computer of the 21st Century* [67] is one of the first attempts in computer science to predict future technological development by story telling. In a similar way, this thesis started as a short story about a near future scenarios focusing on quantified self devices, as contemporary trends of technological development suggests to. Besides the technological aspects, this thesis focuses more on human aspects.

An overview of the implementation of values and its effects is given in *Values in Design* [54]. It objects the proclaimed technical neutrality for non-trivial technical objects and states that values are implemented, often unknowingly, due to the objects intended usage. The goal of the value in design research is to discover how values are implemented, and which consequences follow. Consequences can be seen in current discussions about ethical decisions executed by artificial intelligence, over the influence of technical inventions (e.g., social networks) on power structures (e.g., democracy), or unconsidered effects on third-person-parties (e.g., in surveillance scenarios). From the effects of values in design follows *value sensitive design*. Value sensitive design is based on the proposition, that if values are implemented whatsoever, good, reasonable, ethical values can and should be implemented from the starting point of design process. This leads on the one hand to methods how to achieve those values in software projects, and on the other hand poses the question, which values to prioritize. This connects to our work, as we also look at the risk of implementation of "naive" quantified self technology, and ask in which way

different values can be created or maintained.

An idea how values can implemented into software is described in [56, Chapter 13]. Here, Value Sensitive Design consist of 4 different steps which are included during the software development process. The steps are *Value Discovery, Value conceptualization, empirical value investigation* and *technical value investigation*. During these steps it is searched for values which might be affected, the opinion of direct and indirect users and indirect users are included in use cases and system design, and they are also asked to evaluate prototypes and inform about their concerns. The goal is to find clever new technical ideas that implement values of the users. This connects to our work because it shows how narratives as we create them, can be introduced to production development cycles. In this thesis, the narrative is fictional, based on real live experience. In production cycles those narratives would be created with the help of stakeholders, their experience, ideas, and concerns.

Current development trends for quantified self can be observed from the sociological side. Duttweiler and Passoth give an overview in the introduction to "Leben nach Zahlen"[29, Chapter 1]. Herein, motivation, ways of usage, goals of usage (for individuals and institutions), impact on users, types of users, and development of the society using those devices are summarized. While the goal of usage is often assumed to be self-optimization for improved performance, e.g., in sports, mood, diet, time usage, also self-experiments are important especially for avant-garde users. Most individuals use self-tracking for problem solving in their daily life by optimizing themselves. In both cases meaning of self-tracking for users often comes from giving them control and responsibility over their own life, but can also serve as self-expression. The impact of device usage is shown to be activating and (self-)disciplining in nature, whereby it is shown that feedback and reward have greater chances to succeed in manipulating behavior. The perception of number visualization from self tracking is shown to be believed more neutral and objective and believable as comparable feedback from specialist on a field because it is based on bare numbers. This leads to a feeling of increased autonomy and self-actualization for a wide range of individual users, which makes it a sociological phenomenon. The neutrality of those devices is ambiguous, because during the technical development many decisions for interpretations are made, but they stay invisible for the user.
The impact of self-tracking bases on the emotional response their usage elicits. Basic emotions while checking the numbers are passion, shame, delight, and revulsion. Self-tracking can also lead to a shift in the perception of the self, for example the visualized data can be considered as a digital, "more real" doppelganger, or as some kind of addi-

tional, external senses of the self. Furthermore, quantified self devices shift the perception of users bodies either in noticing more of themselves, less of their bodies (only believing numbers), and it can create a dissonance between the visualized numbers and the physical sensations. Also the usage of self-tracking leads to an instrumentalization of the body, instead of "being the body".
For the evaluation of the shift of individuals and societies with quantified self exist many open questions. The change with self-tracking is not concluded and there are still ways to influence the change. This paper comprehensively shows concerns which are also concerns covered in this thesis. Whereby Duttweiler and Passoth give a more broad overview, this thesis concerns the effects concrete technological objects.

In the same book Mämecke [46] analyzes shifts of power and responsibility through quantified self devices in work environments. While quantified self devices first promised autonomy, the relationship of dependence between employer and employee is strengthened by additional health management. Power shifts gradually towards the employers side, which obtain information about their workers in aggregated form and try to use it to optimize production. For example, unhealthy lifestyle would lead to more sick days, could lead to discrimination of employees based on their way of living. While power shifts to the employers side, responsibility stays with employees who need to adapt to this new form of control.
Mämecke claims, that if employers hold power over the work environment, they are responsible for its contribution to the employees health, too. Besides excessive self-care of employees, ways to create less sick days and to improve production would be to provide a healthy work environment which reduces negative stress and promotes a lot of regeneration time. But these ideas of change are often left out of the discussion. Instead, individual employees need to balance out unhealthy work environments in their free time. Mämecke describes this shift by reference to the term "burnout". It was originally used to describe individual suffering due to excessive workload, but emerges now prevalently in discussions about economical losses due to individuals suffering from this illness and forms an obligation for individuals to practice self-care.
Mämecke's discussion is interesting for this thesis because it supports the idea of power shift. We discuss the shift of the power not only in the work environment, but also towards other institutions. We also look how devices could be designed, for that autonomy can be maintained.

Lupton [45] investigates motives of self-tracking devices. She distinguishes five existing modes of self-tracking that differ in the motif of tracking, as well as the subsequent use of

the tracked data. Therein, the *private self-tracking* is based on private motivations of the user and private usage of the tracked data. *Pushed self-tracking* has a more pedagogical and motivational goal, and is also suggested to the user by other actors. *Communal self-tracking* is done by the user as part of a group. Also the data is shared to the group. This can be for example social media self-tracking communities. In *imposed self-tracking* scenario the user cannot decline the use of a self tracker, for example when those devices are used in educational facilities. In *exploited self-tracking* the tracked data is used for a different purpose than advertised, e.g., by selling them to a third party. In real life examples the modes intersect with each other. Lupton discusses further the effect of self-tracking to the users selfhood. She states that the responsibility to optimize oneself to a pre-given standard is placed upon the user. This is done under the promise to make the best of the users life chances. These observations are interesting this thesis as we see in which ways goals, stated by the users environment, directly influences them and alter their behavior. It also shows that there are real life incentives that oppose the interest of users, which make the manipulation attempt by institutions a plausible risk.

In van Dijk et al. [25] current scientific publications are evaluated for the questions whether users obtain self-insight and change behavior (*self-improvement hypothesis*) by using tracking devices. For this, several models methods how people change are summarized. It shows human behavior change consisting of several stages during which different methods of information and motivation support the user. It shows the examined tracking devices have potential to support users to raising awareness on a specific aspect of their life, and maintaining an already made behavioral change. The devices can help visualizing small improvements for the user. Furthermore, devices cannot make decisions for users and that causal links created on the basis of the tracked data is difficult and prone to errors. Also the question is raised, how second processes influence the observed behavior change, which are not bound to the tracking device itself (e.g., observer effect). This paper forms foundation for the analysis of effects the intelligent dress can have on users. We use it to examine immediate and longer lasting expected effects.

The *extended chilling effect of Facebook* [47] describes the effect of users of social networking sites altering their behavior due to the perceived social expectations. This happens not only during using the website directly, but also offline. The possibility that an information (in the paper a photo) is uploaded to social media is omnipresent. Since audiences from many different social contexts are aggregated to one circle of "friends", users tend to post only information that is not rewarded with (perceived) social disapproval from any of those audiences. This shows for this thesis how many people are concerned about their

impression to other people and how they change their live to get approval of others. It also shows, that impression managing appears in a digital world. It helps to understand and to examine how users might react under constant monitoring.

General psychological models are used in this thesis to analyze the users possibles reactions to quantified self devices and their reasons. Most influential for this thesis is Bandura's self-regulation theory [17] and Kluger's and DeNisi's feedback intervention theory [41]. Self-regulation theory describes how people can change themselves, to achieve certain goals, and feedback intervention theory describes how feedback effects people and which kind of feedback in which situations enhances or diminishes the chances for behavior change. Since behavior is always accompanied by motivation, goals which initiate behavior are also explained. Those two models give insight to argue in which cases quantified self devices might work, and which risks can occur in certain circumstances. It also gives us material to argue, why certain design of devices might not contribute to peoples happiness when it works against their goals and their motivation.

In the last part of this thesis we examine the proposed development for the impact of life in a society as current western societies. Which parts are beneficial for users and which ones might harm the wellbeing of the individual or a society. Justification for our argumentation bases on several philosophical introduction papers and books about ethics in general and ethics in computer science.

Hoerster [35] introduces interest based justification for moral judgment. For this, he describes the distinction between moral standards, and their justification. He writes that rational wishes of individuals and societies justify universally valid norms. This thesis argues alongside interest based moral justification, whether an impact of quantified self is in the users best interest and which characteristics are responsible for the decision.

Pieper [50] describes ethics as basis for societal cohesion. People work together on the basis of several basic ethic rules to create a safe environment, if everybody fulfills them. She describes the development of ethics from this first consideration through the broadening to universal requirements, and the arising problems. Furthermore, she discusses the increased need of ethical rules, which comes with increased power of humankind to do harm (e.g., towards nature), and the shift of perception in societies which ethical rules are necessary. She describes how applied ethics in specific fields of human activity create ethical rulebooks in that field (e.g., in medicine).
Most interesting for this thesis is her justification of informed and autonomous individuals to make ethical decisions, as part of personal freedom. As basis for these decisions,

imaginative considerations and power of judgment are enough to make themselves appropriate pictures of situations. This is a base for the ethical part of this thesis. We create and examine such a picture, to reflect the responsibility which comes with the power of creating quantified self infrastructure towards the goal of meeting the arising ethical requirements.

In *Ethical IT Innovation* [56] Spiekermann approaches the ethical topic on a large scale. This book offers a wide range of background knowledge about ethics and its application into IT. She emphasizes *values* as orientation point in the IT-Development process, describes how values are implemented during the first decisions in the development cycles, how to become aware of them, and how sensitive values can be implemented in a reflecting way. The topics of the book span from IT, over psychology and philosophy to management with the goal to enable hands-on development of ethical soft- and hardware. In this thesis, information from several chapters are used, e.g., what values are, and why and how they are important in the users life. Also, which concrete developmental decisions are made in the design of our conceptual dress and which values are affected by it. Further, at several points in this work we will cite different chapters, due to the respective topics.

3 Quantified Self Technology

In current society a trend towards optimization of individuals exists. People search for perfect careers and résumés, perfect bodies, perfect health and sleep, perfect vacations, perfect food, perfect families and circle of friends, perfect hobbies, perfect homes, and perfect property. It can be argued that one goal behind these optimization endeavors lies in the hope for self-determination, and at last, autonomy. Expert knowledge to improve peoples life in this way are often perceived as insufficiently fitting on the individuality scale [29]. Therefore, people try to create their own data on their behavior, bodies, moods, and environment. They use it to explore and/or optimize themselves. Information which enables additional knowledge for self-exploration is often implicit, unspoken, and invisible [29], and therefore hard to obtain without technological help. So, quantified self devices help to reflect certain information and their patterns back to the users to open up the opportunity for self-exploration and self-optimization.

Sociology reveals three risks in the usage of quantified self technology [29]. For once, the effects of the permanent monitoring. Research on monitoring people has a long history, already. Secondly, the loss of self-control in favor of external control by devices and corporations, for example, when machines decide who gets credit at a bank and who doesn't. Thirdly, the loss of perception of humans as 'humans' in favor for a perception of humans as accumulated numbers. For example, when people are seen in a statistical fashion, not as individual human beings with different needs and goals, details of the world are unseen, and fairness lacks, for people who are not or mis-represented by the numerical system. Another concern is seen in the change of the human interaction [29]. For example, performance society increases individual anxiety about the own performance and affects the believe of the ability to persist in this society. So people compare themselves increasingly to relatable groups. Quantified self technology is collectively used in sports, self-help groups, and among friends and families, with the implicit assumption that the additional extrinsic motivation by social comparison helps towards an optimized version of the self.

This chapter gives an overview over quantified self, its definitions, its users, and its technology. In later chapters those aspects and their effects are discussed more deeply.

3.1 Quantified self

The urge for people to measure themselves has a long history. Diet tracking goes back to the antiquity [29]. The first technological devices supporting self-tracking were mechanical scales in the 16th century to measure the body weight of its users. Back then, Sanctorius of Padua tracked weight and food intake for 30 years to research metabolism. Today, more sophisticated devices support quantified self. Fitness trackers measure steps, heartbeat, sleep, and temperature. Smartphone apps exist to track diets, weight, emotions, habits, or productivity (or at least time dedicated to work). The goal of the quantified self practitioners is exploring themselves over self-reflection. The device oriented quantified self movement started in the 20th centaury when computers decreased in size. At first, a strong motivation of early pracitioners was to gain indepence over their own bodies, independent of medical expert knowledge [29].

For this work we define *quantified self* as the activity of representing humans in form of numbers. The representation does not need to be comprehensive. Also a subset of values can reveal the points sufficient information. *Quantified self devices* (or applications) are technological entities, i.e. hardware devices or software applications, which help to monitor selected characteristics. The devices can interpret the tracked numbers, reflect them, and initiate actions based on their evaluation results. Quantified self devices do not need to work in a stand alone way. They can exchange data on any scale, from personal device which is worn on the skin to the next coffee maker, but also to large infrastructure entities, e.g., health insurance companies. Every place the data flows to, in any form, raw data, anonymous, pseudonymous, or even aggregated and interpreted, belongs to the quantified self *environment*. Most of todays quantified self devices are primarily made for reflecting numbers and motivating certain behavior on the users end.

Quantified self devices are developed under certain assumptions about their effects in real life. One of them is the self-improvement hypothesis. It states that “Users obtain (self-)insights by examining their data and subsequently change their behavior based on those insights” [25]. So the goal is to motivate behavior change towards improvement, i.e. self-optimization. This means, devices work correctly if users gain the ability to optimize themselves in their chosen activity. Optimization can come in various forms, from fitness

goals for a longer life [29], to money spending habits, to time spending habits, but also to become independent of emotions by better handling them [25]. Currently a large amount of self-optimization apps can be found for smart phones covering all these topics. The charm of quantified self applications is their promise to give neutral feedback without distortion of perceptions.
Self-tracking can be done actively or passively. Active self-tracking requires taking notes about things (analog or digitally in any application), for example, adding lunch to a diet application. This helps to raise awareness of the action while it occurs and therefore gives immediate feedback (e.g., "Oh no, the burger I had for lunch contained a lot of calories. - Should I really add this pie as dessert or do I eat an apple?"). Passive tracking is done automatically and not necessarily linked to immediate feedback. It only works over additional devices and offers information, which is otherwise hard to obtain. Next to self-tracking, monitoring can be used for less introspective reasons. For example the monitoring of sleepiness of people who drive a car can have positive effects, it the car warns drivers before they fall asleep. Another aspect of quantified self applications are gamification. Gamification is the activity to add extrinsic motivation to activities to motivate people for usage of the device [52]. This can work over points that represent achievement which unlock certain feature. For example the app "Wokamon" [6] lets users collect crystals for their step count. On the screen are little monsters which and the crystals can be used to level them up or to buy them food, clothes and other things. Another example is the app "Zombies, Run!" [7] with audiobook capability. In this game people who jog need to increase their speed when zombies appear. The assumption behind gamification is increased motivation and costumer loyalty.

We see quantified self technology is accompanied by inventive creativity from companies. While the users goal lies to a large extend in self-improvement, companies themselves are also interested in increasing customer loyalty [52] and their profits. The users reaction on quantified self devices is summarized in the next section.

3.2 Users

Duttweiler et al [29] summarizes current research about users of quantified self devices. The research is mostly based in the USA. We can distinguish between two fundamentally different kinds of users. On the one hand, there is a small number of avant-garde users,

who strive for self-exploration, self-experimentation, and try creative new ways of self-tracking. They creatively try to find coherences between the measured data (e.g., diet and ability to concentrate) and try to manipulate them. Such users can be found for example in Facebook groups and Reddit subforums. A look there reveals everything from commercial usage to ideas as extreme as setting self-build sensors under the skin to measure things and other prosthetic extension of the self. These avant-garde users are not of concern for the rest of the thesis. On the other hand, there are users who obtain their quantified self technology by mainstream institutions, as stores, health institutions, and sport clubs. These are the ones this paper focuses on. Research about users shows that users have different goals [29]. 83% of all users want to improve their health, 84% want to self-explore and gain knowledge about themselves, and 18% want exchange about their results with other people. Further numbers from Duttweiler et al [29] state, the usage of quantified self technology is mostly used to solve specific problems for users. For example, when users feel overweight, they buy fitness trackers in an attempt to reduce their weight by using it. Most users of quantified self devices are young (age 18-34), and between young people and old people different goals could be determined. A group of younger users (age 25-34) mainly followed the goal for improved fitness. Another group of older individuals (age 55-64) followed the main goal of extending their lifetime. The lifetime of the devices depended for a large part on usability factors. For example ugly design was a reason to discontinue usage, as well as inconvenient usability. Also devices broke from every day mistakes, e.g., washing them in washing machines. Also the devices were sometimes perceived as bothering and patronizing. Nevertheless, in 2014 65% of users used their device already longer than a year. In near future, sensors become smaller, and technology advances itself in terms of computer interaction. Therefore, we can expect that with increased usability usage becomes increasingly seamless and invisible and users get more and more used to self-tracking.

3.3 Technology

The technological side of quantified self devices concerns with tracking human features, how they are transcribed into data and how they are evaluated and reflected back to users and environment. In this section we focus on technology which primarily collects data for interpretation of the users physical state, as they could be added, for example, in smart clothing. Smart clothing is the introduction of quantified self technology into clothing. Sensors can be added into clothing and textiles have the ability to change according to

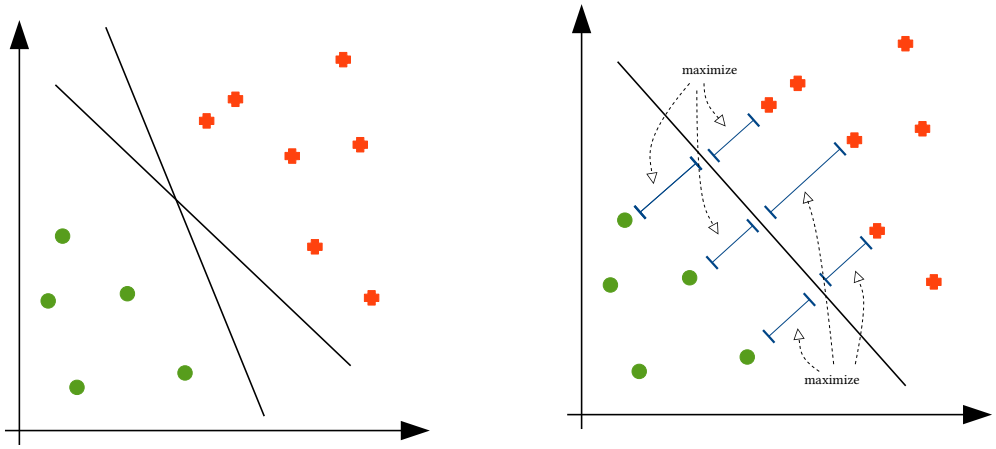
certain stimuli. For example, they can change their colors due to air pollution [12] and forms due to diverse stimuli [37], helps with the communication between musicians [18], or tracks health based information [10].

The kind of data which is tracked is chosen on the basis of what is needed to interpret a certain situation. Primarily this can be sensors for physical activity, but also sensors for context information are of interest. For example, it makes a difference for the fitness interpretation of an individual whether the individual normally lives at the coast, and suddenly goes hiking in alpine mountains. The body needs to acclimate to the situation. A context sensor about the current height would support the interpretation. The collected data needs to be of certain quality [56]. It needs to be accurate, consistent, complete, reliable, and semantically described by metadata[1]. Interpretation of data to create knowledge can be done in various ways. Some interpretation is straight forward, for example, a daily step count. Some interpretation algorithms are complex and from human perspective in activity not comprehensible. The last ones are commonly described as "smart". Smart technology means that devices take over tasks autonomously or only under sparse human monitoring. Such tasks are presumed to be executed correctly if they actually help users. The ratio between the complexity of a task, and the correct execution under a large level of autonomy, decides how smart an application is perceived. Smart algorithms can be found in relatively small application as spellcheckers, over interpreting physical sensor values towards a count of burned calories, towards large scale big data application. They can learn from previous data and discriminate entries into groups under certain goals. For example, a data entry containing address, age, physical activity and spending habits can be interpreted in terms of creditworthiness by algorithms without individuals understanding why exactly this interest rate is appropriate.

To get an idea about big data algorithms we shortly summarize support vector machines. Those algorithms act as our representative of how large amounts of data can be used to extract knowledge algorithmically. Support vector machines consist of two parts. Firstly, they separate datasets (regression), later they can be used to classify new data into the priorly created groups of data (classification). So, support vector machines [26] find groups of data, which are similar to one another. The data is represented with i features, in an *feature vector* of length i, creating an i-dimensional space. In two dimensional space, that would by a vector of two points $\langle x, y \rangle$. An example is shown in Figure 3.1a. Support vector machines search for hyperplanes that separate similar data into groups. Theoretically, many hyperplanes can achieve separation of datasets (compare

[1] This is discussed with its effects in depth in Chapter 4 and Chapter 6.1

Figure 3.1a), but support vector machines search the hyperplane with the largest margin, i.e. the largest distance to all points (compare Figure 3.1b). Often, points of data do not represent themselves in distinctive groups, as in this example, but are much more scattered among each other. In this case, certain mathematical tricks allow to do the same thing in a higher dimensional space.



(a) several vectors can divide the dataset

(b) Support vector machines search the hyperplane which maximizes the distance to the points

Figure 3.1: Support vector machines can discriminate data into coherent groups of similarity

Feature vectors can consist of many different features. From address of a person, to average step count, to shopping habits. And the goal of these algorithm is to find groups with certain characteristics. There might be obvious results, e.g., a coherence between shopping habits and address, but theoretically, they would also find a group of people who succeed their daily step goal, and only eat bananas, even if this groups was not expected to exist. The important question is what these classifier actually classify and which meaning it has. If humans are represented by numbers, and their features are classified, it can get hardly comprehensible for individuals why they were sorted in one group or the other, e.g., why they are getting a credit, or why they have to pay more for the same vacation. Also, if algorithm learn from data which represent humans, the data always includes the prejudices and discrimination of the respective society. The algorithm also learns those too, and they will be reflected in the results.

The way data is represented towards users defines the last aspect of the technological side. Results can be returned in pure numbers, which is the core of quantified self.

But results can also initiate things happening in the real world, without showing the numbers explicitly. For example, notifications can be send, without users knowing how the notification was calculated. An example for this is showing advertisement which fits to the users current situation, e.g., menstrual hygiene products days before the expected menstruation, or advertisements for diapers after a visit in the maternity wing at the hospital.

In the following Chapter we introduce the concept of a smart dress and deepen aspects of the human-computer-interaction design as well as the technological implementation by reference to the dress.

4 The Dress - A critical Design concept

In the past, several approaches in various disciplines have been made to conceptualize future objects and their consequences on living. Mark Weisers *Computer of the 21st Century* [67] from 1991 describes everyday life filled with ubiquitous computers included invisibly to objects like memopads, screens and coffee machines. Personal and public information is at the fingertips for every user. He describes this scenario in form of a short story, following a day in the life of a woman called Sally who interacts with the machines in a natural way. Further concepts of future living can be found within the field of *Critical Design* [28]. Herein, artistic objects elicit narratives of usage in the mind of the viewer. Inspired by these approaches, we conceptualize a smart dress in this thesis. For this, we extrapolate currently available technology, add them to clothing and create a narrative of usage around it. The narrative user story serves to extract stakeholders, the effect of using the dress on them, and ethical problems which would occur in a real life scenario. The goal is, to find ways to engineer quantified self devices and environments, which prove themselves benevolent towards users and to avoid transgressing boundaries and causing discomfort or harm.

4.1 Story of a dress

As Sally wakes up, her first glance goes to the alarm clock. 20 past 6, and her iron tiredness mixes slowly with a shy sense of panic. In a very short while, she has to be in the office. The alarm clock stopped waiting for her to enter a light sleep phase to comfortably wake her up. She would have been too late.She reminds herself, to go to bed earlier today, to reach the next light sleep phase.

After showering, Sally prepares breakfast for herself. Sugar free cereals, some fruits, coffee, the usual. Because of the lack of exercise at her office job, a healthy breakfast routine was suggested to her. She even got an official notification for it. And recently,

she started to notice all this new advertisements for organic food. Since the health insurance companies started an cooperation with vendors for smart clothing, the prices for healthy food decreased noticeable. Probably, many people want those products, so more is produced, she explains to herself. Health cannot be bad, so why should she worry. Besides, she is a little proud of herself that she made the transition from Nutella toast to cereals with fruit.

The office is already frantic when she arrives. A close deadline, and everything happens at once. To top it all, the coffee machine only servers her decaf. She had set the privacy options of her dress, so it communicates now with the office appliances, to simplify her everyday work. Doors unlock when she wants to enter, calenders synchronize and remind her on stuff, and tracking of movement helps her being more aware of herself. But evidently, high caffeine consumption is incompatible with her health program. A nice co-worker helps her out, and fetches real coffee from the machine for her.

As the monthly team meeting reveals, Sally and her co-workers are less physical active than other neighborhood offices. The overall count of *health points* decreased again since the last month. To battle stress in workers and to prevent illness, the health insurance companies introduced health points. They can be collected in many different activities and occasions. From healthy food, over applying stress management techniques, to physical exercise. Persons, who gather many health points can reduce their monthly membership dues. Also employers receive bonuses for the monthly dues of their workers. In this way, employers are said to be motivated to create healthy work environments, and employees are motivated to use those opportunities. Also, a sense of community is said to be increased, so people feel more comfortable to engage in social activities for their health. Sally likes the concept and enjoys the monthly financial bonus from the health insurance company. So she sets her dress to send her notifications for physical exercise or warnings when she is stressed.

When her dress nudges her upper left arm a while later, Sally focuses on the inside of her body. She feels, indeed, a little jumpy and stressed. She also feels a little back pain from sitting all the time. She stops her work and withdraws herself to the self-management room for a short meditation. Behind her, the door clicks to “occupied”. She moves along balance boards, punchbag, treadmill, and meditation cushions. She shortly looks out of the window (rainy, grey morning), and closes her eyes. Listening to her breath, she focuses on the feeling of her feet, her legs, her body, back, and shoulders. When her attention reaches the face, she notices the tenseness of her forehead. As she notices, they

relax by themselves. When she opens her eyes again, the colors of her dress are a little bit brighter than before. It's working, she thinks relieved. At least, she had done her part for the collective health goal, she adds with a slightly more bitter note, when she meets her co-worker later. He holds a pizza box and this won't help the collective count of health points.

This evening, Sally arrives exhausted at her door. The stress of the day had taken a toll on her. Everybody had been loud and hectic, and no real physical exercise was done yet. Sally drags herself up the stairs, ignoring the elevator. Only few steps are missing for the daily goal. If she jogs in place while toothbrushing she will still meet the daily step count.

The next day is Sally's free day. She needs to do assignments for university. She enjoys working on them at local coffee shops. A bus would take her there in ten minutes, but she developed the habit of walking the distance. If the pulse gets high enough, the walk will be logged as *active phase*, as exercise, in her health log. She also noticed, when her heart is racing for other reasons, e.g., stress, because the bus is too crowded, she gets an activity phase for free. Dependent on how fast the bus drives through the city traffic, the system would log it as jogging or bicycle exercise. It can be comfortable to skip the exercise, but she hates crowded buses, so she started to walk more often. The assignments for university aren't working out for her today because she cannot think straight. So after a while she just walks back home. In the afternoon, Sally receives a doctors notification, warning her of an upcoming cold. She knew this was coming. This happens normally about three days before her menstruation starts. She asks herself, when the systems will learn, that also women use them, and goes to the store to buy tampons.

In the evening, Sally has a yoga appointment with her friend Theresa. For this, she uses her smart workout outfit. The TV is on, and the session starts at 8pm. The yoga instructor shows postures and speaks through the flow. Over smart clothing the instructor can check the postures of the participants and correct them. Sally is relieved, that visual images per camera became redundant over smart clothing. So she feels no need to tidy up her living room before rolling out her yoga mat. Camera transmission is optional now. The courses became free of charge, when they started to take place at home. Sally likes this option, but Theresa is often annoyed by it. The number of participants increased, and many of the instructions which are overheard by all participants base on Theresa's mistakes. Her performance is distinctly worse in comparison to the other

participants. After the exercise, all course participants can see their posture quotient. A number which describes how correctly they hold the positions, and Theresa hates to be always on the bottom of the list. She also does not try to achieve better results. The reason is, Theresa often does not feel well, physically. The pressure to be as good as the others makes her feed disadvantaged. When she first got her smart workout outfit, she had been highly motivated and collected many health points. At the time, everything that had mattered to her was collecting those points, like an obsessive game. She constantly exercised and forgot to eat. In the end she became very thin and lost a lot of muscles. Since then, physical effort became discomfort for her. She deactivated the daily movement and step counter on her smart clothes completely. The only other way, to receive the health insurance bonus, was to enroll in the online courses. Theresa financially relies on this bonus, so she takes one course per half-year. She chose the easiest one (Yoga for Starters) and does it so unmotivated, that it is just enough to avoid a *fail* grade at the end. Sally enrolled in this course mainly to support Theresa. The course is actually too easy for her. Her posture quotient is always in the upper third of the list. So, Sally wants to take a different, more advanced course, next time. She hopes Theresa will be able to cope with this situation.[1]

4.2 The Smart Dress

Smart Clothing can theoretically be any kind of clothing. Underwear, socks, sportswear, and pajamas can have all have their own (sub-)set of functionality. Since the concept for all of them is technologically similar, in this thesis smart clothing is mostly represented by a dress. In this chapter the technological functionality of the smart dress concept is introduced.

4.2.1 Physiological Sensing and Evaluation

Smart clothes constantly track physiological data over the skin. For this, several sensors to measure various physiological parameters are included into the fabric of the dress. The sensors extract information about the physical state of users and allows conclusions about their physical and emotional state (compare Fig 4.1). The *ECG* (Electrocardiogram) measures the heartbeat over the electronic output of the heart muscles. This can be

[1]The original German text of this story can be found in Appendix A

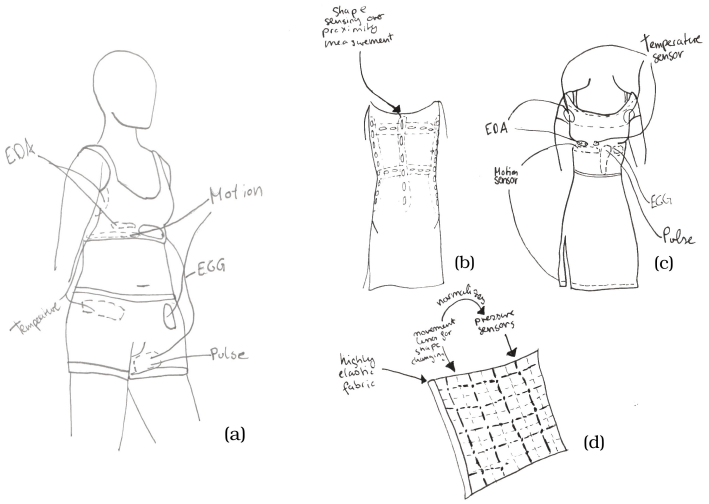


Figure 4.1: Smart Clothing sits tight and applies several sensors to the skin.

used to determine temporal heartbeat or seizures, but can also be used to identify the six basic emotions happiness, sadness, fear, surprise, disgust, and anger [53]. Another sensor measures the *electrodermal activity* (EDA), which describes how well electricity is conducted over the skin. The change of EDA is based the amount of sweat which is produced by the skin. Thereby, EDA depends on the sympathetic activity of the nervous system, which again reacts to emotions of users. So, measuring EDA indicates the level of emotion somebody is experiencing [49]. The *pulse* reveals information about the heartbeat in general. Further, sensors can measure the *breathing rate and deepness* out of the movement of the upper body transmitted by the expansion of the lungs. The dress can also track changes in posture can be over stretching of the fabric. The dress measures also *Temperature* is measured and can give information about possible fever. Information derived from physical data becomes increasingly meaningful with the completeness and reliability of measured data. Tracked data can be evaluated with big data algorithms, as support vector machines to create knowledge about the users. In the story, the created knowledge, particular the aspect of health, emotional stress, and exercise affect a lot of Sally's daily routine. She addresses them by optimizing her routines, according to the devices concepts of healthy living.

In the dress scenario physical data evaluation and direct interpretation is shown in several circumstances. At the first day, light sleep phases are detected, which can be done for example over a mixture of movement data and body temperature. Later the day, the

coffee machine only serves decaffeinated drinks to Sally. Such a decision can also be based on data as blood pressure or heart rate. Sally has set her dress to remind her to move regularly, which happens as she already feels pain in her back. Since back pain is a common result of wrong postures in sedentary behavior, technologists can try to prevent it by evaluating postures and checking whether users move enough. The posture is also evaluated for the yoga class on the next day in the story. On the second day, the story mentions *active phases*, which can be determined by posture, pulse and location. This is an example for behavioral tracking, i.e. the classification of physiological and contextual data into users behavior. The doctors notification on the second day is triggered by a higher than normal temperature. This is probably interpreted as a sign of fever but is also a common symptom of premenstrual syndrome. Emotional sensing is based on the interpretation of physiological data. The focus in the story lies on the occurrence of stress, and the achievement of a calm state. Sally's dress nudges her to remind her of her current stress level. A way to determine the stress of a user is the evaluation of electrodermal activity, which shows the activity of the autonomous nervous system. Since the autonomous nervous system is activated in many circumstances, other features and also non-physiological contextual sensors (cmp. section 4.2.3) are needed to accurately determine the state. To transfer the evaluated information to the users, feedback technologies are needed, which are discussed in the next section.

4.2.2 Giving Feedback

The dress can communicate with users and give them direct feedback. While, theoretically, every human sense can be used to transmit feedback, in this scenario tactile and visible notifications are used. The goal is seamless integration of feedback, without checking smartphones, or any other proxy devices. The goal is to let users feel something so that they know instantly what is meant. If this becomes comfortable, users may react on feedback without thinking about it consciously. For every feedback application, the kind of feedback should be defined. It can be given continuously, or intermittently, on demand, or disruptive. It can be stopped with user interaction, or without. To create a meaningful user experience, the effects of those decisions need to be considered. Vibration sits directly on the users skin. It has the capability of being brutally disruptive, intimate and cannot be avoided easily, since the dress cannot, for example, be undressed in an instant. Color changing of the dress has the special property of being visible to other people and therefore shows personal information to practically everyone.

Figure 4.2: The vest transmits information for musicians during performance. The vibration elements for communication are sewn on the back of the body to look like embroidery. (Image from [18])

The dress vibrates to inform its user. Vibrating elements are distributed over the dress and can either be placed near to each other to create vibrating fields or as singular entities. Vibrating fields are capable of transmitting information in form of a range. This can be seen, for example in [18] where it is used to create interaction between audience and improvising musicians (Fig. 4.2).

The range-like information of an vibrating "screen" helps to transmit control information more intuitively as for example an iconic representation with a learned meaning could. For example, in case of pitch for musician, it could show how far off-key the instrument is. Theoretically, range-like information can also be transferred via single entity tactile feedback, for example by the intensity of vibration. Thereby, there is only deviation in *one* direction perceivable. With two dimensional fields, more diverse information can be encoded and also intuitively transmitted.

Single vibrating elements are more useful to convey iconic meaning. Location or specific patterns of vibration stand for specific information. This is similar as the functionality in today's smartphones, in which, for example, different messenger application vibrate differently. The meaning of those iconic vibrations have less intuitive capabilities. They have to be learned to understand them.

Another challenge with tactile feedback is to avoid overwhelming users. To understand

messages, users need to get them relatively slowly in a comprehensible way. Also, tactile transmitted information receives different level of attention due to the users current occupation. While disrupting users, which are highly concentrated, can lead to small shock-like moments, users in a hustle may not even notice the vibration. So an estimation is necessary when to interrupt users with which information and feedback intensity.

In this thesis, the dress gives iconic pre-configured notions to users in form of short vibration patterns.

The other direct feedback possibility of the dress is the change of colors. Color changing fabric can used both for information transmitting as well as fashionwise. A combination of both is likely. Similar to tactile feedback, colors can used for range-like information and can encode even more various information due to the additional dimension of color (hue, saturation, lightness). Therefore, colors depend less on the time parameter to convey information or can even display full pictures. Characteristic for color changing ability is that users need actually look at the dress to receive the information, and the information is also visible for other parties. Enabling fabric with color change due to physical values, the clothing will likely become more part of the person (in comparison to today's clothing). The reason is that people can see what is going on inside the wearer. It can therefore become a part of social encounters and is similarly uncontrollable as the human body itself.

Our dress reacts on the relaxation-stress level with increased brightness when users feel emotionally well. We play with the idea to give the stereotypical phrase "you're lighting up the room" a visible meaning. To follow through with that idea, it becomes possible to enhance the image that the user shows the world with purposeful information, as "Don't talk to me", or "I'm important", and being much more flexible as with typical clothes.

To use feedback mechanisms meaningful, they need to hold a balance between requested and interrupting feedback. To enable feedback to automatically adjust to context but also to avoid the problem of overwhelming users, there need to be rationales for all kinds of information. They need to be rated against each other continuously to decide which information is transmitted to the user. Also, there needs to be configurable "mute"-options to allow the user interruption free breaks (but maybe not muting *all* interruptions, life saving ones might still be useful). The required notifications within certain situation depend on context. Therefore, they are hard to anticipate and might change often. So additionally to the contextual adaption and pre-configured preferences, the user needs

to have a quick way to switch notifications on and off. We assume, the dress provides that.

4.2.3 Contextual Sensors

Broader technical capabilities of the dress are used to create a context for collected physical data. The goal of contextual data acquisition is to interpret the user state as precisely as possible. For that, context data serves to dissolve ambiguities. Any imaginable sensor can be used to attain context data, and in this work we assume all kinds of sensors which are in todays smartphones or could be thought of be built into one. The dress is extended with location (geo-based and height) and movement data. Other imaginable sensors for smart fabric would include air or breath analysis (as seen in [20]), brightness sensors, cameras, or microphones.

The concept of context is understood differently in computer science and sociology [27]. While computer scientists often assume context as the pre-requisite to users actions and therefore aim to use it as trigger for computerized actions, theories in sociology see the context fluidly changing within the process of human action. Thereby, context is rather a result of actions, negotiated by several parties or objects. The sociological view sheds light on the endeavor in software development that using N sensors to interpret the current state is prone to be faulty because the whole context does not exist yet. It is incomplete. Even if context was a comprehensive and complete construct at a certain moment, since context is part of a changing process, it will be wrong soon. The challenge in smart textile (and general ubiquitous computing) is to support the fluidity of context. To support this, Dourish [27] mentions the option to display context to users. This idea contradicts with the traditional approach of computer science to make software "transparent", meaning hiding inner workings of software and providing an interface behind the software just does it's job (preferably perfectly). The visualization of the computers state ($\approx$ context) would work analogously to two people in an conversation, talking about the conversation itself (e.g., "What you said was mean", "Could we talk about something else?", "What do you mean?"). In the next step, the workings of software could be made adjustable and configurable in a fundamental way. This needs to be distinguished from customization configuration of current software, which often only scrapes the surface. In the end, the negotiation of context and meaning of actions should have a place in smart objects because it seems to be an intuitive way for users to handle things. This view contradicts

today's interpretation of "smart", of having an object handling things for users without their intervention.

In the case of the dress, the traditional computer science understanding of "context" is used. Movement and location sensors help to identify physical data as an activity. When users change their location, and the dress moves considerably, the user is probably walking or running, which then would fit to faster heartbeat. If only inner movement of the fabric is detected, without change of location or physical activity, there may be a windy day. On other occasions, location and movement data help to distinguish between emotional based stress and physical activity. Even if the coherence between sensor values are not algorithmically implemented as single decisions as in this example, the occurrence of specific sensor patterns would also be recognized by artificial intelligence algorithms.

One problem of using negotiated context with smart textile is that the design idea of the dress does not support on interaction. The basic idea is rather, to require as few interaction as possible. The dress is designed to "just work". There are no options to convey information towards the dress intentionally. A dress which asks for context could add another annoyance level for the user, because it requires user attention throughout the day.

In the dress scenario effects of wrongly understood contexts can be seen. The pre-menstrual increase of body temperature is therefore wrongly identified as illness and a doctor is automatically informed. A context negotiating approach would have had the chance to ask Sally how she feels, whether she has a fever, and the next steps could have been agreed upon. Also, when Sally takes the bus, and she has increased heartbeat, it is interpreted as jogging, which depicts also a typical contextual misunderstanding. Movement sensors in shoes could help to solve the context question in the computer-scientists way, as well as question the user. Theoretically, the user dialog would also need to be open ended, so that new contexts can be established by the users. This is the advantage of the approach to negotiate context with devices. Knowledge and interpretation capabilities can be extended without necessarily updating the hardware, as the traditional approach would require.

4.2.4 Knowledge Creation, Data Usage and Data Sharing

This section describes what data and knowledge actually is, how knowledge creation works and the circumstances of data usage and data sharing.

Technology bases on the process of tracking or receiving data, evaluating it by specified rules, and then releasing the results in the real world. Thereby, the letter can mean to give feedback, or a computer initiated action which changes the analog world. The process of measuring data and calculating results can have different scopes, from simple website user counters, to complex big data interpretation or autonomously acting robots or cars. Thereby, the algorithmic interpretation of data differs largely but on a meta level, its pure calculation of data. Since computers are built by humans, their inner workings and design base on human experience, thats why we find similarity in the way humans form their knowledge. Data is perceived, interpreted, and then it results in an action.

For a definition of knowledge we use the definition Justified True Belief as described in [39]. Justified true belief consist of three parts which need to be fulfilled to call something knowledge.

Justified True Believe: S knows p, if and only if:

1. p is true.
2. S believes p.
3. S is justified in believing p.

The first condition is the truth condition. It states that something which is not true, cannot be known. Thereby, it is necessary to distinguish between things look like, and how things truly are. Only the latter is truth. Moreover, truth does not necessarily need to be accessible. Something can be true, without anybody knowing about it. An example for this is scientific research, which searches truth that exists before it is discovered. The second condition is the believe condition. It states that people can only know what they believe. Thereby, it is insufficient to be believe something is highly possible. Only *full* belief is enough belief for this condition. Critics argue that people can know things which they do not believe to be known. Such a thing happens if people think they forgot a fact, but if they are asked for it, they have the feeling that an answer can be right (with insecurity) and then the person realizes that the answer was correct. In this case, the brain knew it and the person didn't believe it. The last condition is the justification condition. It connects the other two conditions. It establishes the fact that lucky guesses are not the same thing as knowledge, since knowledge is justified and guesses don't need an explanation. Justification can be obtained from S in several ways. Either personal

experience and features of p coincide. A more specified point of view is, that p is justified if and only if, p is the best fit to S's evidence. Another external approach describes justification as valid if certain procedures were used to obtain the knowledge. These things could be for example be cognitive processes, or logic. This would hold even if the first glance on evidence does not directly suggests a belief.

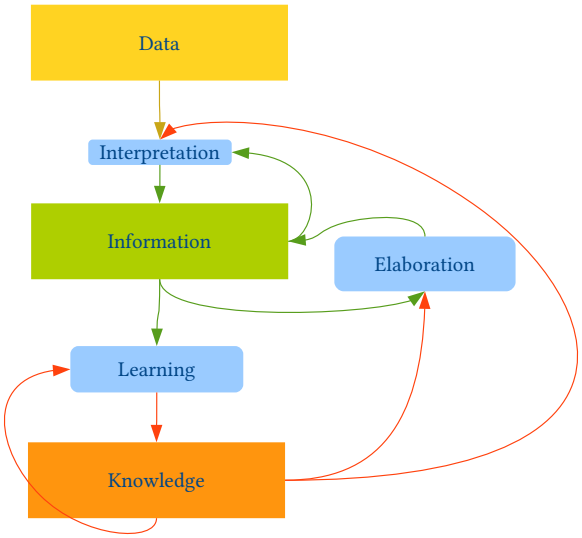


Figure 4.3: Processes of elaboration, interpretation and learning create knowledge from raw data. The coloration is to clarify the input and output of the respective step of processing.

On an abstract level, knowledge creation, by computers or humans, follow the process in Figure 4.3 [56, Chapter 5]. This process brings together sensing, context, and also user feedback functionality. At first, data is measured (or perceived), then interpreted in some way, and information is created. The raw data includes the output of the sensor. In this first interpretation process, also information and former knowledge is included in a feedback loop. The interpretation process therefore includes knowledge and information from prior experience of the perceiving individual, resp. knowledge from the designers and developers of the technological product. This additional information can be understood as part of the context. While raw data are single values, the interpretation creates structures between those. Gathered information can be further analyzed and interpreted, which might generate new or refined information. Knowledge is something that needs a beholder. Traditionally, this is a person who knows the information. So to create knowledge for users, the information is transmitted to users, who use it for their own inner knowledge creation process. On the technological side, since the learning

structure of the brain is algorithmically recreated in artificial intelligence application, also a technological "blackbox" can be created, which holds information and learns. The result is for example a classifier, who is trained with information about objects, and sorts similar objects into categories. These kinds of blackbox software can also be seen as knowledge, since they hold interpreted information.

For quantified self devices as the dress, knowledge creation is based on data from sensors and from data exchanged with other devices or infrastructure. The output of all sensors and transmitted data can be pre-processed and, e.g., become part of a feature vector for further analysis. In the dress scenario, next to increased temperature, features as shopping behavior, or coffee consumption are added to feature vectors and are included in the interpretation. The selection of feature and the data quality of those measurements are crucial for the validity of the result. If an important factor from the analog world is ignored, the results can become useless. This is why quantified self application aim to measure as much context as they can get with an increasing number of sensors (compare Section 4.2.3). To create meaningful results high data quality is needed. Data quality is determined by four characteristics [56, Chapter 5]. *Accuracy* of data includes syntactic correctness, semantic representation of a situation and the handling of duplicates. Data needs in general metadata to describe its dimensions. It is needed to correctly interpret the subsequent steps. Metadata is for example measuring units or parameters of sensors. Also data can loose validity if it is too old. Sometimes data can be measured to sparse or fluctuate too much to find a trend. Another aspect of data quality is consistency. The question is whether the data seems to contradicts itself or other measured data. Consistency problems often happen from racing conditions during concurrent data operations. For example, one part of a dataset is used, then it is overwritten by another process, and then the rest of the dataset is read by the first process. This ends in flawed datasets. Databases usually include consistency checks, but in traditional written software, this can also happen. Another part of data quality is completeness. Data values can be unknown, but also the knowledge of circumstances for the unknown value is important. It differs whether the data is just not existing, if its existing, but not known, or if it is not known whether it exists. For example, the dress measured the heartbeat of an individual and the interpretation comes to the conclusion that the heartbeat is relatively slow. It raises the question whether, this is due to measurement issues (data is missing) or if the heartbeat is really that slow.

As described in the Section 4.2.3 about contextual sensors, the interpretation and knowledge creation can produce faulty results from wrong assumptions, from biased raw data

and from bugs in the software. In these cases, information loose quality during the interpretation process. Justified true belief is affected in these cases. If data is flawed, then the truth condition is affected, and failures in processing and assumptions affect the justification condition. Including bias from assumptions of developers and from within raw data itself, decisions from software can by no means be considered objective. Examples for bias from assumptions are found as personal default goals in quantified self software, as comparison of users results to average data, or as the setting of thresholds and metrics, for example the color changing range of the dress. Default goals are assumptions from developers in the worst case or scientifically determined recommendations in the best case. The bias in average data can come from one sample group, using certain devices and the device mainly uses their data as basis. Users, who live differently from the average person of this group, might be marginalized.

The problem with the knowledge creation process is that it pretends objectivity. People assume each calculation step is logically correct by itself and that data is flawless. But the feedback and knowledge gained is not necessarily true following the justified true belief conditions. The objectivity, neutrality and correctness which computers are believed to be are only beliefs but not knowledge. Respectively, feedback from quantified self devices, as the dress, need to be handled with care and not treated as instance for correctness. In relation to quantified self, devices offer just another opinion or belief, not the truth. Therefore knowledge gained from the devices need to be questioned by users. Data usage and access to data and knowledge is part of quantified self devices and the dress scenario. The usage and sharing of data is part of an ongoing discussion about data protection. Hereafter, we define *data usage* as knowledge creation processes on tracked data. In the dress scenario, the knowledge creation processes include calculations of stress levels, estimating current health states, tracking exercises, comparing yoga postures, and also comparing employees health against each other. Data sharing is any transfer of data. Either as raw data or as knowledge. Also, access to devices is sharing of data, and additionally access to direct interaction with the usage. Data sharing by transfer of data is not explicitly mentioned in the story, since it cannot directly be seen by users. From a bottom up perspective data is shared from devices to providers of services. This data is associated with certain users, to calculate the price for the insurance. Several implementations are thinkable which differ in their privacy. One example, is storing all raw data from the devices on a central server and letting the knowledge creation process run there. This neglects common privacy standards. An alternative would be to push the thresholds and calculations to devices, and the devices only share their gained knowledge.

In this case, there would be a bit more privacy, but not all types of knowledge creation can be done this way. To protect privacy of users, stored data can be anonymized or pseudonymized [56, Chapter 5]. Pseudonymization of data means that datasets cannot be linked to an individual. Since certain features are very specific, they influence the privacy. Identifiable information like address, name, and day of birth render all datasets identifiable. Certain characteristics like rare illnesses can also affect the anonymity level. The less specific the information attached to a person, the more private the persons are. Also the re-linking of attribute must be so expensive that it does not pay off for the ones who try. In case of the dress scenario, Sally's employer and co-workers only see the aggregated information of exercise achievements of the group. This is some kind of anonymization. Directly installed anonymity and pseudonymity procedures increase the complexity of software. Hence, motivation to create access possibility on the devices for potential software updates also increases. The kind of access to devices always has consequences for security, and with it comes the potential for abuse by unauthorized parties. Another kind of data sharing is between institutions. Data can be used by second institutions to gain knowledge about individuals. It would be abuse if the information is transferred without the individuals informed consent or if the data is used to harm users in any way. Also sharing of data between different institutions increases the risk of information being linked and further knowledge is obtained. For example, conclusions about financial wellbeing of a person might be concluded from a combination of health data, data about food purchase, jobs and place of residence. Such conclusions might be wrong and unfair for individuals, even if they are profitable for companies and give correct information over a majority of people. Consequences of such calculations could be how much interest individuals pay for their credits. Data sharing also includes the ways in which the data is shared. This can be for example by technical communication, by transfer of raw data or knowledge to second institutions, but also by selling of companies. In the dress scenario, data is shared between different devices as coffee machines and intelligent dresses, but also between the yoga course companies, the health insurance companies, employers, and doctors. Data and knowledge is not only valuable for financial reasons but can also be used for law enforcement agencies. A current discussion about this is the usage of data for pre-crime detection [11, 9]. Pre-crime tries to single out individuals who are assumed to commit a crime in the future by certain characteristics. The goal is to prevent crimes from happening. Critics claim that pre-crime subverts presumed innocence and is therefore unethical. Also computer and network surveillance is already used for prosecution. It is unlikely that law enforcement agencies would not be interested in quantified self data in general. To protect users privacy, developers need

to think of all these possibilities while developing devices, so that risks are minimized for users. This approach is called privacy by design. Pseudonomization and privacy need to be implemented by default and all risks need to be transparent for the user.

Communication between devices is another main feature of the dress and another form of data sharing. It is also another form to gather contextual information and to influence the users analog world. Information exchange can be executed over short and long distance. In short distance, broad- and multicast communication is essentially helpful to communicate with many surrounding ubiquitous computing appliances. Long distance communication is used for sharing of data for larger services or infrastructure. This is used in every context, for example social media, health infrastructure, urban infrastructure, or hobbies. The dresses communication acts according to privacy rules set by the users, and is pre-configured according to privacy by default (compare: EU General Data Protection Regulation [3]) In the story, users configure themselves, which kind of appliances and services their data will be shared with. Settings can be configured subject to certain characteristics, e.g., settings can only apply locally. So, stress levels can be communicated to the coffee machine *at home* or *at work* to adjust the caffeine, but would not communicate with public coffee shops. Also physical posture is shared only with selected entities and services, and the sleep interpretation data is shared only with one specific alarm clock. Increased sharing of data to the environment, also increases the risk to loose control over it. As described for data sharing, early anonymization is especially important but also merging of data from several sources at a higher level need to be thought of. The more data circulates, the more data can be merged, and the more room for abuse is formed. The difference with intentional data sharing by the devices producers is, that in the former case, at least the company has some control over the data. If the devices share data to other devices autonomously, e.g., over defined communication interfaces, they loose this control.

In this section we examined the construction of knowledge, and how it is formed by computers and humans on basis of directly tracked and context data. It also showed that knowledge from algorithms needs to be used with care because algorithms are susceptibility for bias and abuse this objects the algorithmic reputation for neutrality. Increased sharing of data increases the possibility to merge data and to create patterns, which again reveal knowledge which again is biased. In the end it is difficult to reconstruct how certain knowledge was created and in how far it can be trusted.

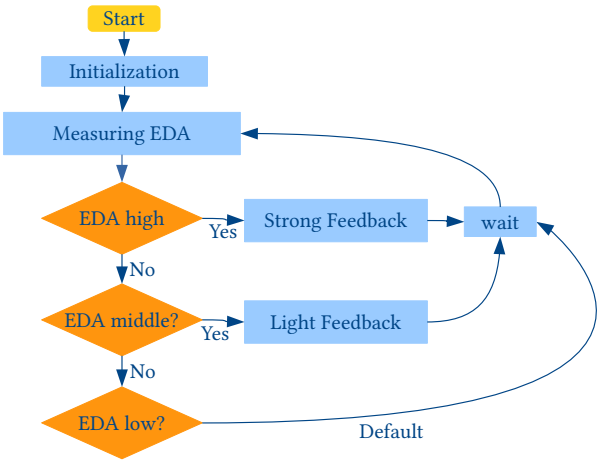
4.3 Technical Feasibility

A dress as described in the story is created with a near future in mind. Most technological components exist, also smart clothing exists already, but these products aren't matured. Furthermore, there is only low prevalence and nearly none infrastructural support. Many use cases as described in the story would need a much larger prevalence of intelligent clothing.

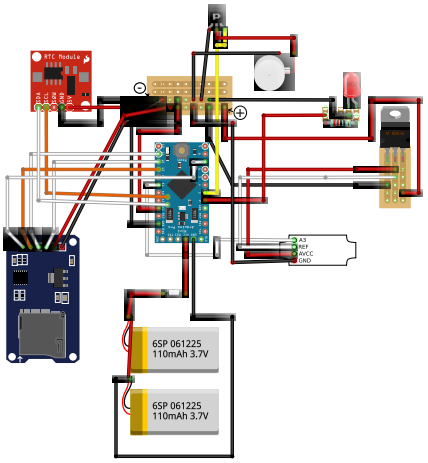
To create a such a dress on the technological side several components need to be specified. Its requirements emerge from the major tasks of the dress: measurement of physiological data, interpretation of measured datasets (locally or remote), communication, tangible feedback, and color changing fabric. The measurement of physiologial data can be either done with classical sensors, sewn into clothes, but also new sorts of textile can be used [37]. Polymers, large molecules which exist naturally but can also be created synthetically, can be applied to fabrics and are able to react to physiological changes. They can either be laminated onto, waven or knitted into fabrics or added into threads which are used to create the fabric. Through this process the added polymeres interfere embedd more seamless into textile integrity, in comparison to additional microelectronic elements in fabric. For example in [37] polymers react on change of pH-values, moisture, temperature or light. Thermochromatic polymers can change their color due to the current temperature and reached the market already. Furthermore, computing power becomes increasingly smaller and hiding computers in objects is ongoing research. Since 2013 there are computers as small as $1mm^3$ [44], which would be easy to hide. Also vibrating elements can be included into clothing to create tactile feedback [18]. It is a question of combining those elements to create dresses as describe in the scenario. Some clothing with similar functionality to the dress already reached the market. For example, a shirt for the gym [10], which tracks heart rate, breathing rate and balance of the user. In a straightforward approach for a proof of concept and with basic technology an intelligent sleeve was created for this thesis.

4.4 Proof of Concept - The Stress Measuring Sleeve

The idea behind the stress measuring sleeve comes directly from the story. The sleeve is supposed to measure the stress of a person and if a certain threshold is exceeded, it vibrates to nudge the wearer into a more relaxing behavior.



(a) Program loop of the stress measuring sleeve



(b) Technical design of the stress measuring sleeve

The program flow is depicted in Fig. 4.4a. During initialization phase an optical and tactile feedback is given to users so that they know its working. Then, it measures the electro-dermal activity (EDA) of the skin in regular intervals. Since sensor data fluctuates, the average value of the last 10 seconds is used for the next step in the program. If the mean EDA value exceeds a certain threshold the feedback is triggered. How strong the feedback is, i.e. how strong the vibration is, depends on the EDA value. We assume that stressed persons need stronger feedback to even recognize vibration on their arms. Also an optical light blinks with increasing brightness. Since vibration strength and brightness of the LED is hard to assess, also the pattern of the feedback changes. Strong feedback vibrates three times in a row, light feedback only one time. Since we assume an always vibrating sleeve can be quite annoying for users, the notification is short and happens every two minutes.

The hardware is depicted in Fig. 4.4b. For underlying computing power we used an Arduino Pro Mini. Additional to the EDA sensor we used, an LED for visual feedback, vibration motor for tactile feedback, batteries, an real time clock module to map EDA values to concrete date and times and a SD card module to record the measured sensor data for evaluation purposes.

The completed project can be seen in Fig. 4.5b. For simplicity reasons the interior was sewed between two layers of standard fabric and the whole sleeve is closed with a zipper. The LED on the back of the hand lights up for feedback, while the vibration motor is giving the tactile feedback. The whole design is quite basic since it is not the main scope

of this thesis. Unfortunately, in the end some hardware problems occurred which fixing would haven taken too much time. So we refrain from analysis of test data. In a more sophisticated approach different materials would be needed, for example, light effects can be integrated in a more sophisticated way. In this example only two features were used, EDA value and time. Furthermore, all interpretation of the situation was created by hand. We see in the upper software description that even in this short example many assumptions are made. Especially, the calculation in which cases and how often the feedback is given is arbitrary.

(a) The stress measuring sleeve lights up to give feedback.

(b) Interior of the sleeve.

Figure 4.5: Realization of the stress measuring sleeve.

This project shows, that main features of intelligent clothing can be implemented in technological control circuits of relatively small experimental projects. The implemented features measure inner human states, render them perceivable over different senses, in this case, tactile and visual, and also nudging users towards certain physical states or behavior. The sleeve is a smaller, more experimental version of the dress in the story, which changes its color due to stress, vibrates to inform the user over the current stress level, and additionally communicates to second parties. Next to making the inner state of users perceivable over additional senses towards the users themselves, the stress becomes visible towards second persons, by lighting up the LED, resp. the dress changes its color and communicating to appliances. From this project we see that implementations of dresses as in the story is mostly a matter of scale, precision and optimization. In the next chapters we examine the impact of such technology on humans, on their social and infrastructural environment, and on the impact on individuals by these environmental changes. Also we examine which of these effects are desirable or not, and how to influence technology to avoid undesirable effects.

5 Effects on Users

To analyze predictable effects of smart clothes on users, we look at concepts from psychology and sociology, which we summarize in this chapter. We use these concepts to see in which ways smart clothes establish their influence and how users feelings, behavior and relationships are affected. We look at concepts which give us insight about the effectiveness of quantified self to achieve its self-proclaimed advantages and possible side effect the usage of quantified self.

5.1 Motivation

Motivation plays an important role as the basis for behavior [17]. Reasons for people to track their physical activity, emotional states, sleep or food can be quite different. Their motivation can be intrinsic or extrinsic, belong to standards and goals people have for themselves. Their motivation can be short- or longterm and can change over time. Thereby, technology, e.g., big data applications, search for stimuli which motivate people to certain actions, e.g., buying something. When those stimuli are used with increased regularity and sufficient success, users start to expect them. Other kinds of motivation as altruism or empathy do not receive the same benefits of optimization, and run the risk of being marginalized. In the case of quantified self devices, there are two major goals arising from motivations: increasing awareness of behavior, and optimizing behavior [34, 29].

Which physical function or behavior is tracked, depends on the underlying motivation. Lupton [45] identifies five different motivations, which describe how self-tracking finds its way in users life:

Private self-tracking bases on the the *personal* goal to increase self-awareness or to optimize their lifes (*self-improvement hypothesis* [25]).Collected data is only used privately or shared with chosen others, like friends. Similar, Mämecke [46] sees the motivation of early

self-trackers in an emancipatory endeavor to decrease the dependence on "paternalistic" health care systems.

Pushed self-tracking occurs, if the incentive for tracking comes from another actor, not users themselves, but is adopted into the users life by their own choice. The goal of pushed self-tracking is to motivate self-determined behavior change. For this, the collected data is visualized in an motivational way to provoke an emotional reaction which eventually leads to the behavior change.

Communal self-tracking includes the sharing of collected data as part of social movements. Therefore, one motivation is to belong to a social group. Communities can be created on different backgrounds, e.g., locally or interest based, as city-wide, or all joggers in the same age range. In the dress scenario, communal self-tracking occurs as comparison between different companies and their employees health levels. Those systems are implemented as top-down structures, in which companies determine the workings of the system. Single users have little influence on the working of the system but can experience social positive rewards and negative sanctions, e.g., if they choose not to participate.

Imposed self-tracking changes from the user-based motivation and users as beneficiaries to benefit other entities as companies or governments. It is characterized by users having no choice to decline the usage of trackers and the processing of data. An example would be the usage of the geolocation and stress level by employers to calculate the productivity of employees. The motivation to capitalize and discriminate on employees health shows Mämecke [46], as current services offered to companies, e.g., for calculating the monetary productivity of an employee in dependence to the number of sick days. On the other hand, imposed tracking can be very useful and in some circumstances life saving. For example, tracking the sleepiness of drivers. Nevertheless, such systems need to be balanced to values as, for example, privacy.

Exploited self-tracking is characterized by usage of data for completely different things without the users consent or dismissive of potential negative effects on the user. A current example is the implementation of social credit points in China, which uses information from many different sources as online shopping companies, social media or camera surveillance to implement a social status. Also it is mentioned that the detection of users lifestyle, e.g., how many people play games on computers [43].

We can see the difference of intrinsic and extrinsic motivation [62]. Motivation for an action is *intrinsic* if it comes from a persons inner goals, and can in Luptons analysis

only be found as part of the private motivation. *Extrinsic* motivated actions base on influences and rewards, which do not match the persons intrinsic interest but represent as thematically unrelated rewards or sanctions. For example, working at something can either be done to learn something new, or can be a paid job. The former is intrinsically motivated, the latter extrinsically. Both motivations can overlap.

Research about the effects of self-tracking is mostly done on the basis of personal motivation (compare [25, 16]). And also todays health tracking devices are mostly still implemented privately in the users lifes. Nevertheless, we see increasing social pressure to optimize oneself [46] and motivation becoming increasingly extrinsic and can enhance to a fear of consequences, in form of imposed or communal motivation. This extrinsic motivation is able to change the behavior of people (compare Section 5.3.2) but can only lead to self-satisfaction as long as personal goals are activated [17]. Furthermore, extrinsic motivation can reduce motivation and effectiveness of an action [61]. Since prospect of self-satisfaction is a major influence on motivation and behavior change, we doubt that people who are not (or low) personally motivated will effectively change their behavior. They won't do it, do it reluctantly, won't muster up effort, and they will stop once the external pressure is off.

The women in our story, receive externally pushed, communal, and imposed motivation. Though, the reactions of both of them differ. Sally is okay with using the smart dress, implements it in her life, and is intrinsically motivated. She changes her behavior to eat healthy, let the dress count her daily steps, reacts on the dresses notification, and allows data sharing with her work environment. The latter is decided by Sally over the configuration of the dress and is therefore a form of pushed motivation. Settings (and benefits) are offered by the device and users decide themselves about the usage. It is not private self-tracking since Sally does not see her data, and then spontaneously decides to share the data at her workplace. A question at hand is, whether the monetary motivation by the health insurance companies is pushed or imposed. While there is some degree of control for users, i.e. whether to use daily step count or fitness courses to retrieve the monetary bonuses, to not take part in it, is sanctioned. For Theresa, the latter option is not available, because she is in need of the bonus. She herself has therefore no choice to decline the health activities, even if she states that she does not want to do them, and that she probably has good reasons for that. So she is exposed to imposed motivation. We see two problems here. First, the forcing factor depends on the wealth of insurants. For wealthy insurants, the monetary benefits can act as pushed motivation. Second, insurants as Theresa, may suffer mentally and physically because of the imposed sport

courses. When people suffer from unspecific “not feeling well”, or “just don’t want to do this” we cannot assume that exercise is working in their interest, and they need just “a little motivation”. The story mentions a period of time in Theresa’s life when she had too much physical activity and lost a lot of muscle and body fat. Since bodies are no computers, the existence of a seemingly healthy body, does not mean that there are, for example, undiscovered mental or physical consequences of that period in her live. People address indifferent symptoms like this by listening to their bodies, and decide to take a slow approach. The imposed motivation on Theresa contradicts this natural behavior. Another example for this kind of natural behavior is, when getting a cold people tend to stay inside instead of forcing ourself to jog through the November rain, because this would make the cold to break out completely. By imposing physical activity on someone, the natural feeling for healthiness is attacked by standardized rules. This is especially ironic in our dress scenario because the physical activity is yoga, which teaches listening and honoring the body and the bodies boundaries.
Theresa is in a double bind situation, where she can only loose. A double-bind situation [4] is defined consisting of three parts, two contradictory requests (bindings), one of which must be chosen. Therefore, a person cannot choose any “right” option. The third requirement is that meta-communication or any other way to resolve the situation seems impossible. Theresa either listens to her body and feelings and stops physical activity, and would experience monetary sanctions (first bind), or she forces herself to do yoga, where she learns, not to force herself and to listen to her body and feels physically bad doing it. The physical discomfort act like a punishment itself, because it can be interpreted as the bodies way to tell people they are doing something wrong (second bind). At last, with an insurance company as the request maker, it is unrealistic to hope, that the rules will change for Theresa, if she complains, so meta communication is also a nearly hopeless endeavor (third requirement). So she is unable to resolve the situation by meta-communication. Also, she does not have another way out of the situation, so in the end, she endures the imposed physical activity and is miserable while doing so.
Communal motivation can be found in Sally’s workplace. The company compares the activity level of its employees to the activity levels of comparable companies. It goes so far, that the company has a “self-management room” for the employees to optimize their health. Sally also sees her co-worker eating pizza for lunch, which she judges as unhealthy. This judgment is a direct sign of peer pressure. She cares about the food of her co-worker because her personal success depends on the groups’ health. This is, because the feeling of success is the reward for participating in the cross-company fitness comparison. We also see, the more positive side of communal motivation, with Sally’s and

Theresa's decision to join the yoga course together, which increases the motivation. On the other hand the comparison among the Yoga participants, and exposure of Theresa's mistakes in the course makes her feel bad. She cannot get positive outcome out of the situation.

In the dress example, users get motivated for yoga by monetary bonuses. In contrast, yoga itself is traditionally spiritually motivated. It discourages self-optimization and encourages self-love, self-respect, but also respect towards others and not harming them. For example, many yoga practitioners are vegetarians because the philosophy of yoga includes the virtue of "ahimsa", which means nonviolence against humans or animals [1]. In our dress example, the yoga course is overfraught with self-optimizing incentives, and the traditional acceptance baseline is ignored. Instead, the self-optimization approach contradicts the yoga idea and reduces it to gymnastic exercises. This way, it is unlikely that Sally and Theresa start being vegetarians, or doing other empathic or altruistic things they learned in yoga. Motivation by altruism is marginalized through the technical implementation of comparison between yoga participants, by calculating pose correctness quotients and monetary motivation.

Another well known concept for motivation can be found in Maslow's hierarchy of needs ([56, Chapter 4.4.3] after [48])[1]. This pyramid includes intrinsic values (values which cannot be reduced to other values) which are basic for human growth and happiness. When underlying values are not satisfied, the upper values cannot be achieved. A lack in the underlying layers motivates humans firstly to fulfill this requirement. If the requirements are fulfilled, they naturally are motivated to fulfill the needs on the next level.

The needs are depicted in Fig. 5.1. The most basic needs form the physiological needs which are needed for survival. The body needs to feel good, e.g., no hunger, housing, painlessness, sex. If people lack on this level, e.g., are hungry, they will not care (as much) about the upper layers. If people are physically satisfied, they care about safety. No physical or other harm is pending. If those needs are fulfilled to a satisfactory level, people have social needs. Being part of a family, having friends, being loved and having people they can count on. The next higher level are self-esteem needs to support the ego and identification of people. They find out what they can achieve with their own two hands (or minds), they get social recognition, and earn self-respect. If these are given, humans tend for self-actualization. They want to find out who they are and how

[1] This model is a basic model and many more modern models are researched and used in psychology. Nevertheless, we use this one for its simplicity and prevalence among literature on human-computer-interaction.

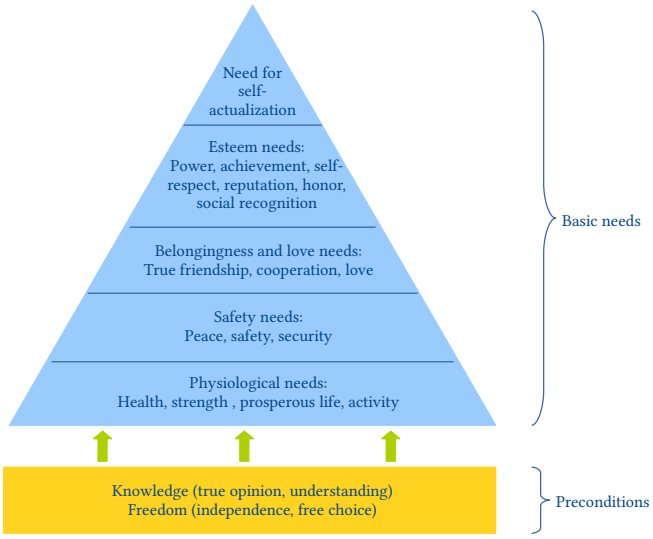


Figure 5.1: Maslow's pyramid of needs (Image after [56, Chapter 4.4.3])

they fit in the world. Also, the impact on the world in a more broader sense becomes important. One point of criticism of this pyramid is that it is ego-centric and values as altruism only exist on an additional, overlying level of transcendence, where others might argue that, e.g., altruism acts also as a basis for the fulfillment of other needs as safety or social belongingness. Also, even if underlying layers lead to a very strong motivation to fulfill them, and can lead to a lot of sorrow and misery, people sometimes also pursue goals of the upper layer at the same time. The levels of the hierarchy are not rigid exclusion criteria but describe severe motivation and tendencies to gain happiness for individuals. The precondition for the fulfillment for any of those goals are knowledge and freedom. Knowledge is needed to understand the world and to create true opinions about it. Without learning and knowledge the next levels cannot be reached because ways must be found to fulfill the underlying layers. Freedom is a necessary preconditions for several reasons. First, testing of the environment is necessary for learning, for this people need to make different choices. Second, only if they can choose how they live, and how they fulfill their needs in the long run, they can be happy. Not every way works for every individual.

In this section we examined which background motivation exists to elicit human action. For once there is the sociological perspective of motivation by intrinsic and extrinsic incentives. Secondly, there is the structure of private motivation, as shown in Maslow's pyramid of needs.

The usage of a smart dress as described in the story, can help and hinder the achievements of the needs. The following chapters examine which of those needs are effected in which ways. We see that feedback of data offers knowledge, and therefore influences choices based on this knowledge. It monitors physiological characteristics of users and aims to support their physiological needs. Also, social interaction are influenced due to the implementation in the infrastructure and due to the existence of communal motivation. Further, it can influence esteem and feelings of achievements over the feedback it gives.

5.1.1 Standards and Goals

This section shows, how standards and goals of people are structured, and how they are acquired and pursued. Thereby, we call *standards* the overall guidelines people follow. *Goals* are concrete manifestations of those guidelines, which can be achieved by certain actions. Thereby, standards and goals both act as the basis for motivation and action. Goals emerge as stepping stones on the way to achieve an superior standard or as high level goals, which individuals hope to achieve someday. This section is based on information from [17] and [41].

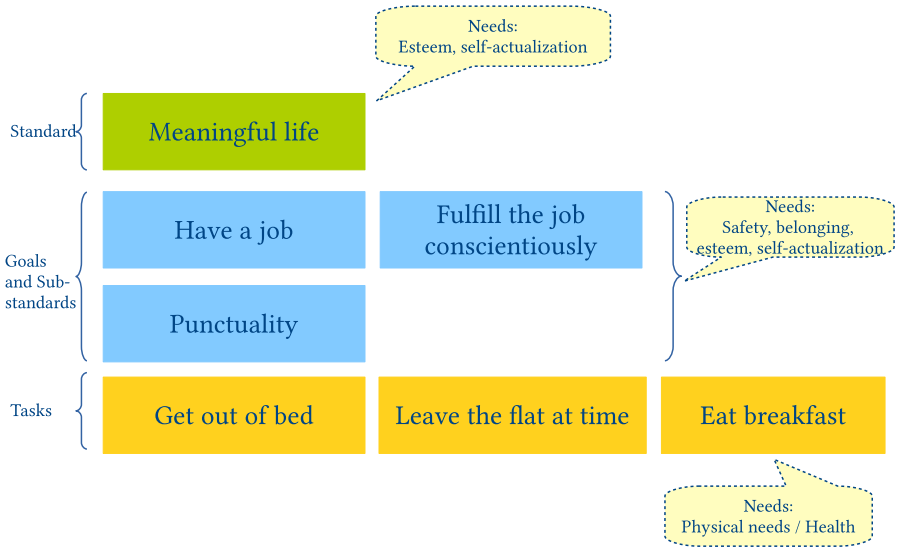


Figure 5.2: Standards translate to sub-standards and goals and then to tasks.

Standards are structured hierarchically with more general standards of the self in the higher layers of the hierarchy and more concrete immediate standards in the lower layers. For example in Fig. 5.2, the standard of having an meaningful live. This standard can

also contribute to needs as esteem and self-actualization. On a lower level, the standards splits into the sub-standard to have a job and to fulfill it conscientiously. For this, another substandard is to come to work punctually. These goals and sub-standard also contribute to other needs as safety, because it leads to income, it can contribute to the need for belonging because of the social interaction at work. Further, those goals help with needs of esteem and self-actualization from the upper layer. On the lowest layer, goals and sub-standards transform into tasks as getting out of bed, leaving the flat, and eating breakfast. Also these concrete task can contribute to different needs, as for example the breakfast helps with physical wellbeing. The upper levels influence the goals of the lower layers, and with achievements at the lower layers, people can get the feeling of achieving the overall goal or standard. Many goal can be translated directly into tasks, especially at the lower layers. This is also interesting when something new is learned. In the learning process [41], people start at the lower layers with very small steps and simple tasks. With their mastery, people gain self-confidence [17] and move their attention towards higher goals and standards. The subtasks are executed automatically and respective subgoal are fulfilled with them. If standards change, or executed tasks do not fulfill the higher goals and people still want to fulfill them, then they concentrate on the lower layer tasks and adjust them.

Standards are acquired throughout life [17]. They have been prescribed explicitly and copied from other people who lived by example. Other standards span across cultures and seem to be intrinsically human, e.g., a meaningful life, money, power, drive satisfaction, or, in a more existential way, surpass death by becoming famous or having children. In societal subgroups different standards are popular and shared, e.g., people in specific religious groups share a set of values. Nevertheless, people are capable to prescribe one standard but live by another. Also, they do not just copy standards from other people, instead they create their own weighted sum. If people experience conflicting standards or are confronted with consequences of their actions, they create their personal interpretation and set of standards which they follow. There are different type of standards, as those for daily activities or moral standards. Moral standards tend to last longer and affect more severe reactions, if transgressed.

Overstepping of standards is accompanied by social and personal sanctions [17]. While personal consequences are mostly invisible (people “feel bad”, Section. 5.3.2), social sanctions appear when transgressing standards become visible. Typical social sanctions are people talking about the transgression, exclusion of groups, withdrawal of trust, and many more. Since people need to be part of groups, social sanctions can be difficult to

bear and work as control mechanism. Social sanctions do not end in personal feelings, but also include concrete punishment by society or authorities. For example imprisonment, paying more for health insurance as in the story, and removal of chances for personal development as denying of job opportunities. Respectively, standards, which people follow, can either be more personal or more socially concerned. On the two extremes of the spectrum, there are some people, who prefer to strongly live up to their personal standards. They tend to stand through social sanctions without (or with less) feelings of guilt and regret. On the other end of the spectrum, people are primarily concerned with social standards of groups and can benefit from adjusting their behavior to current situations. Many people are concerned with both.

The motivation for a certain activity is influenced by goals and whether pursued activities helps to achieve those goals. If those goals are intrinsically motivated their achievement leads to self-satisfaction. In this case, the activity is pursued only to challenge oneself [58]. If they are extrinsically motivated the motivated person focuses on an reward which is not coherently linked to the activity. Achieving the secondary goal of extrinsic motivation is not rewarded with self-satisfaction to the same extend as intrinsic motivation would. This may have consequences for the sustaining and giving up on activities. People, who are intrinsically motivated to achieve something, e.g., writing a specific number of pages per day, endure phases which aren't immediately rewarding [17]. On the other hand, we see that people, whose goals cannot achieved by an activity, leave the activity. For example in [34] the use of a fitness tracker is less lasting for people, who rather want to stop smoking or eating healthier because the fitness tracker itself does not help with this goal. In intrinsically motivated activities, goals and activities can freely be changed to achieve self-satisfaction. In the case of extrinsic motivation this is not possible since the activities are at least pre-determined. In this case, if goals are not accomplished, the motivation also descends, but if that happens, people will forfeit their reward, which can act as a social sanction, especially if the reward is of crucial need. For example, if people are motivated to take part on certain social media for connection to their friends, they cannot simply leave the site without loosing that connection. They do not necessarily have a simple replacement strategy because it needs to provide a similar goal, social connection. Before the rewards or sanctions are experienced, extrinsic motivation act as a thread of loosing the promised reward, whereas intrinsic motivation always includes the chance of getting the same reward, i.e. self-satisfaction, in another way. In pushed, communal, imposed and exploited self-tracking, people get extrinsically motivated, or pressured, to achieve a goal in a specific way. In situations when people have no choice to change the

expectation of the environment, they have three choices left. They internalize extrinsic goals, achieve them with the prescribed activity and get rewarded with self-satisfaction that way. Or they execute the activity reluctantly without internalizing, achieve the goals with much more force (because they aren't internally motivated) and do not even feel good afterwards. Or they do not achieve the goals and suffer sanctions.

In the dress scenario, pushed motivation is transmitted by the dress. Thereby, the dress represents extrinsic motivation, social reward, and social sanction. It can also support private and intrinsic motivation, in a situation where goal can be set freely, and the data is not further processed for another purpose. Sally is extrinsically, but also partially intrinsically motivated while using the dress. Motivation is due to certain actions, and Sally enjoys the yoga course and tries to improve herself there. Also, Sally is motivated to live and eat healthy. The goal creation process was based on external advertisement first, which she eventually accepted as her own goals. This goal also leads to the decision to let the dress communicate to the coffee machine at her office. Her settings let the dress control her caffeine intake. In stressful situations, she ignores the goal because the short time goal to get work done becomes more important. Then, she searches for another way to get caffeine by asking her co-worker to get one for her. So she adjusts her goals to the situation. In the yoga course and gfor the relaxation techniques Sally is additionally extrinsically motivated. Extrinsic motivation is less effective than intrinsic, and also can reduce intrinsic motivation in cases where both are present [61]. So even if Sally enjoys yoga, the number on the highscore might get her distracted. Also, the monetary motivation can take the fun out of the activity, when she feels, that she is only doing it for the money or the highscore list.
Theresa is solely extrinsically motivated. She is doing her yoga course out of the fear of consequences, and is therefore unhappy with the situation. It takes a lot of energy to do something which people are not motivated to do, so she feels tired and is in a bad mood. Also she is in an no-win situation. We saw how the working on fulfillment of own goals is the basis to achieve happiness. In case of Theresa, one of the basic layers in the hierarchy of needs, the physical one, is attacked by the whole situation. The chance to make herself happy is therefore small and increasing happiness is very difficult. Theresa would need to switch goals to improve the situation and probably quit physical activity for a while. The quantified self environment does not allow this, which leads to the previous described double bind situation with contradicting, unaccomplishable motivations and therefore harms happiness.

In this section we saw different models for motivation of people for certain actions.

Reasons for actions can transmitted socially, infrastructural, or come from within a person. Actions serve certain goals, either from the person within, or for others to gain benefits. Personal goals come from the strive of persons to develop themselves to be a happier person. For this, certain personal needs to be fulfilled. Quantified self devices try to influence motivation, under the promise to increase happiness. This dose not necessarily come true and depend on the persons living conditions and also on ethical values as freedom of choice, which are not necessarily positively influenced by devices. These influences and their impact within quantified self environments will be discussed in the following chapters.

5.2 Domestication

Domestication describes the process to include technical devices into users lives. The question whether and in which way objects are used depends on the motivation and goals of the user on the one hand, and the possibilities for usage of the object on the other hand. Promises of goals and usage motivate to purchase objects, and goals of users determine how long an object is used. If objects or their usage are not contributing to the users standards and goals, the usage is changed, the object is dismissed or the goal or standard is changed. But not only users "domesticate" their objects in making it fit to their lives, users can be "domesticated" by the object through the ways the objects offers usage. This happens when behavior or goals are changed due to a devices usage. This chapter shows how both domestication processes work. The process of a user to domesticate an object consists of five several aspects and problems which have to be figured out [65, 15]:

Appropriation is the aspect, which includes the acquisition of a device and the reasons for it. Motivation has an important function answering the question: "Why do I want or need that device?". The motivation to get a device can be an attempt to fulfill personal goals, e.g., people need to save money, so they try budgeting applications. In contrast extrinsic motivation, especially if it comes from other sources, helps establishing goals in a user which implicitly promises to aid certain needs. This can be seen in traditional advertising. A goal is prescribed and a way to achieve that goal is offered, e.g., "You want to be thin, try this calorie counter!". The implicitly addressed need behind the goal may be come from social belonging, or esteem needs, especially under the self-improvement hypothesis. The

fitness goal is one of the prevalent goals in the dress scenario. But also the usage determines which object is needed. For exercises like running, smart underwear might be enough, but for the requirement as comparing yoga postures, a more covering approach would be needed to calculate the current posture.

Objectification is the second aspect. It concerns the question what the object means or represents to the user. This can be any kind of value. Next to philosophical values as introduced in Chapter 6, objects address the basic needs of users and help to achieve their goals. For example, objects can increase reputation and therefore address esteem needs. It can also bring safety or security in users lives. In the dress example, Sally starts consuming healthy food, which address her needs of esteem (she is proud that she made the transition to healthy food), but can also address physical needs, as living healthy. Among others, the dress itself addresses physical and safety needs, when the bonus of the health insurance is financially needed by users, it represents social belonging and esteem over comparison to other people, and it represents esteem of companies, if they collective health level is compared.

Incorporation describes ways of the usage of the object. This includes personal settings within technological objects, but also when, where and how it is used in the analog world. Sally personalized her dress, so that it helps her to consume less caffeine and reminds her that she is too stressed. Theresa uses her intelligent clothing only when she joins the yoga course and do not use it at other times. Also settings over the dress itself can be thought of. For example hiding options, to not show the current stress state of the user, or to the feature to fake a different emotional states, might help to achieve a better incorporation into users life.

Conversion stage is defined by the transformation of usage or meaning through users. The main question is: How can the device be used further, beyond the pre-thought user stories. An example is Sally, who uses her temperature notification once a month to buy hygiene products, since she knows that not an upcoming cold led to this notification but her upcoming menstruation.

The domestication of users by objects is established by their usage. Every device implements ways of usage and defines the spectrum of possible outcomes [68, Chapter I.2]. This is done over the interface design and the configuration depth. What is not open to be controlled by users cannot extend the means of expression of the user. A fitness tracker device might not count calories that were spend in a swimming pool because it is not waterproof. But it might offer the chance to enter the activity by hand, otherwise

users cannot express themselves in the given context. Domestication of the user by the device would happen, if the user starts skipping swimming and go for a run instead, because only this is tracked by the device.

In the incorporation and conversion stages users depend on the capabilities of the device. Not only do they make the devices fitting to their lives, but they adapt to ways the devices suggest their handling. Especially, since devices represent values due to the objectification stage, these values can act as extrinsic motivation to keep up using the object, even if the usage itself might be inconvenient or even contradictory for users wellbeing. Examples can be found in the dress scenario. Sally is taking the stairs to fulfill her daily step goal, even if she is tired. She also jogs in place while toothbrushing. This visualizes the domestication effect of devices and how people adapt to them. Sally is financially, as the value of safety, and partly intrinsically motivated for her own health. Every behavior change to adjust to a device is such an domestication effect. Further effects in the stories are learning to meditate, eating healthy breakfast, and monitoring behavior of co-workers. Other questions are more abstract. In which cases and which ways are these domestications beneficial? In contrast, domestication can lead to seemingly senseless or even unhealthy behavior, as the jogging in place or Theresa's extreme usage which led to illness.

In this chapter, we saw that devices and users influence each other. Thereby devices cannot adapt themselves to users, when these options were not pre-thought. Instead users adapt to devices shortcomings. Motivation is important for the decisions which devices are used in which ways. The following sections of this chapter which inner processes of humans respond to devices. It shows more in more detail, how devices can influence human behavior. In the chapter about ethics (Chapter 6), we examine the question for benefits and risks of domesticating users to devices due to values the objects represent in the users life (as in objectification stage and Maslow's pyramid of needs) and also to more collective values of society. Also we see how domestication process can be included during development of devices, so that value harming of devices can be diminished.

5.3 Methods to Influence Behavior

Self-tracking devices are designed for behavior change. To see the impact of devices, it is necessary to look how behavior change actually works. From this, we can estimate how self-tracking devices impact the changing process, including the opportunities and limits

of devices accompanying the behavior change process. Further, we can look out for side effects which can emerge with the usage of devices and whether they might influence users in their daily life. In the following sections, several behavior change phenomenons are listed that are touched by the implementation of self-tracking devices in users lives. We use them as a blueprint to examine risks, effects, and limits in the usage of those devices. The selection is not comprehensive and models of human functioning are chosen which either emerge from prior human-computer-interaction research or seem reasonable to discuss in the context of quantified self devices.

5.3.1 Self-efficacy

Self-Efficacy is defined as the personal believe that one can interact with the world so that a desired outcome is achieved [17]. People feel good, if they achieve a desired outcome or get discouraged, if they do not. Therefore, self-efficacy depends on specific actions rather than it is a general believe. The persons believe that he or she can do something is influenced by prior experience in similar situations, by observing relatable other persons in similar situation, by social persuasion and by observing own emotions while thinking about certain tasks [33, Chapter 13]. The opposing side of self-efficacy is learned helplessness [22, p. 301-302]. People can learn that their actions do not have any effect on the world. So they stop trying to change adverse situation for the better because they believe their actions have no effect in this situation, either. Instead, they become passive in their actions and this can lead to depression. Quantified self devices influence the perception of achievements by making small achievements visible to users [25]. In the dress scenario, Sally recognizes the effect of her short meditation immediately; she receives the positive feedback over brightening colors of her dress. In this way quantified self devices give feedback about achievement of tasks, and therefore can influence users thinking about whether they can achieve a task. This leads to the challenge, that feedback from devices needs to be *fair*. Fairness means that people receive an sufficiently accurate, unbiased image about themselves, so that they can evaluate themselves correctly and respond in an appropriate manner. Fair feedback on the one hand, needs base on data of good quality but on the other hand must also be fair towards the context of the user [56, Chapter 5.6.3]. This is important because perceived unfairness hurts people. People who feel (and are) wronged have lower self-esteem, take higher risks, and think about themselves as less competent [60]. This shows that the feedback influences the self-efficacy of users because the letter is an paraphrase of the self-efficacy definition.

Perception of failure influence self-efficacy so that people perceive themselves as unable to accomplish a task and this can encourage learned helplessness. Data of bad quality and wrong interpreted raw data can both have this impact, for example by showing inadequate negative results towards users despite them doing fine. For instance, Theresa might be doing good in yoga in context of her current physical state, but when she gets negative feedback, she feels discouraged. She looses interest and only puts in the minimal amount of effort because she has to. This shows, not only the device and its direct feedback are important and influence emotions of users, but also their broader embedding in everyday life. A typical source for bad quality data are when sensors miss activities and interpret context wrong so that users get wrongfully negative results. In this case people create an unfairly negative or positive image about themselves. In both cases people are prone to make inappropriate choices. A positively biased overall reflection might not be bad for self-efficacy. Negatively biased reflections are worse, since they take away peoples feelings of accomplishments and with the self-efficacy. Believe of self-efficacy are also not limited to perception of success on specific tasks. Instead, people transfer the feeling of success and failure to other tasks and generate an overall feeling of self-efficacy [17]. This means that bad quality data or wrong context interpretations can make people feel inapt, not only in the area of feedback, but in others as well.

5.3.2 Self-regulation Theory

Self-regulation theory [25, 17] describes how people tend to optimize their behavior towards perceived social and personal norms (compare also Chapter 5.1.1). In context of quantified self devices it shows in more detail the ways how standards and goals, strengthened by devices, can change behavior. This knowledge can help to adjust devices, so that they fit better to peoples lives and do not manipulate users to actions in a harmful or regretful way. This section summarizes the self-regulation theory of Bandura [17] and extracts points in which quantified self devices can assert influence over users and how this influence would be processed by users.

The basis of self-regulation theory states that people tend to feel discouraged to divert from their norm, and the achievement of a norm serves as a reward. Therein, feedback about performances (e.g., over self-monitoring or feedback intervention, see below), causes spontaneous adjustment of goals towards these norms for many people [17]. Bandura [17] describes self-regulation including three different subfunctions, *self-observation*,

self-judgement, and *self-reaction* (compare Fig. 5.3). *Self-observation* consists of selective attention towards certain things which are observed and acknowledged as feedback to the current action. Also the perception and interpretation can differ, for example in the personal meaning for the user or in which way the feedback is remembered. Anything linked towards the self of the observer and threatens self-esteem or personal competence is prone to be perceived in a distorted way. In case of quantified self-devices, people receive predominantly numeric feedback and a distorted perception would mean to judge them as better or worse as they are. This can be done over excuses like "it was not that bad in the context of XY". While the data from self-observation can be used to diagnose problems in everyday occurrences, learning of new and better behavior has been shown to be more effective over experimenting within the environment and learning from mistakes [17]. Also, observation of own behavior can motivate people to more ambitious goals for themselves. These goals can improve performance, have no effect at all or impair it. The effects of self-observation on performance depend on motivation, data quality, temporal proximity, appreciation of the observed activity by the observers, the level of success or failure within this activity, the voluntarily controllability of the behavior, and whether the observer is more oriented towards personal or social standards. The second subfunction of self-regulation theory is *self-judgement*. Therein, the observed performance is compared to standards of the observer (compare Section 5.1.1). The comparison differs, if an absolute measure for the goal exist. Things that cannot be measured absolutely, are compared towards performances of the someones own past or towards performances of others. People tend to compare themselves towards people in similar social situations and background. This is called social comparison. Group comparison appears if there is an collective goal among people. Thereby, people compare their own share towards the achievement of a group. If they do not feel responsible for an outcome, e.g., their share on the group effort was low, or they needed a lot of help, people get low self-satisfaction from the achievement. On the other hand, people become proud if they take the responsibility of successful actions. The third subfunction is *self-reaction*. This is the palpable reaction by achieving or falling short of a standard. Not only the success or failure of a standard is palpable but also its anticipation. Because the idea of future failure and successes to achieve personal standards elicit respective feelings, people start to influence the future outcome by adjusting their actions. Achieving goals increases positive self-reaction and self-satisfaction. Furthermore, the positive feeling can be enhanced, if they reward themselves for success with tangible activities as breaks, activities or free time. Because people can anticipate and plan those rewards after some standard was achieved successfully, they can work through unpleasant activities. People tend to rate

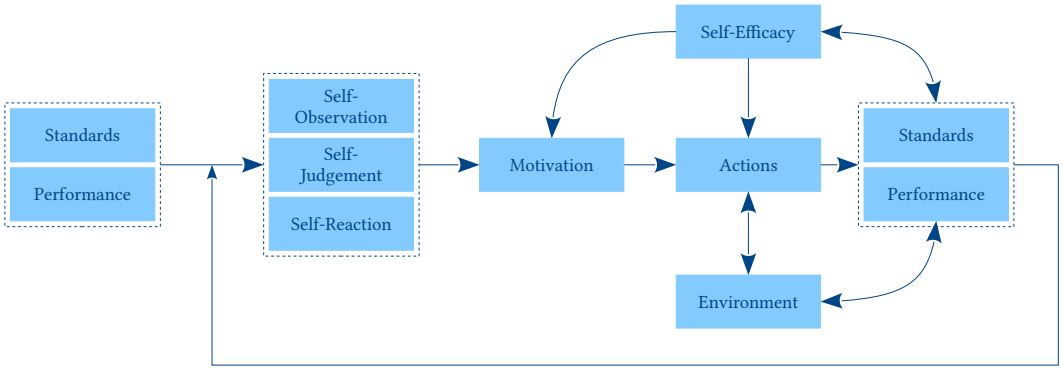


Figure 5.3: Self-regulation is a loop to regulate oneself to achieve a goal or fulfill a standard. The outcome and gap between standards and perceived performance influence future actions, future standards, and images of the self.

self-satisfaction and self-respect higher than material rewards.

So in summary, the functioning of self-regulation to self-improvement and to achieve a standard is similar to a technical control system (compare Fig. 5.3). People have a standard and information about the current performance. They determine their current situation by observing the performance (self-observation), judging, by comparing them against the standards (self-judgment) , and experiencing tangible reactions (self-reaction), e.g., feeling good, or bad about it. This leads to some level of motivation (or no motivation), to plan actions, and then acting them out (including "doing nothing", or "change standards"). They further hold a believe about their own capabilities and ways to achieve that standard (self-efficacy). This can increase or decrease the motivation to act, as well as it can influence the actions themselves, e.g., by increasing effort. The actions result in changes of the environment (or no changes). Those changes show the effectiveness of the action, and therefore the performance level (performance-standard gap). From there, the loop repeats itself and the three subfunctions self-observation, self-judgment and self-reaction start over.

In our story, we can see the effects of working self-improvement with Sally. In yoga class, she compares her own performances towards the standards (self-comparison) and concludes that she is doing well (self-judgement) and further that the current course is too easy for her. She feels good about it (self-reaction), and wants to increase standards by learning more (action). Another action is her plan to change to a more advanced course.

At every step of the loop, parameters can change and impair the effectiveness of the self-regulation. This can lead to dysfunctional iterations. Self-efficacy is crucial for effective running of the control loop. If people believe they cannot achieve their standards, they tend to set themselves lower goals, have less motivation, don't put in much effort and eventually don't see any improvement of their actions. Since no improvement can be observed, self-efficacy is either maintained at the low level or further reduced. This creates a downward spiral of decreased performance and can lead to depression. Also, if the environment is not controllable, it is increasingly difficult for people to achieve their standards. This also interacts with self-efficacy. People with high self-efficacy persistently try new action in difficult environments, and achieve small successes, which help them to move forward. But it also happens that people get discouraged from not achieving their standards due to the environment and eventually give up. Another disturbance of the control loop comes in form of standards. If people have their standards too low, and everything is easy for them, they can become self-satisfied with mediocre performance. If people have their standards too high, they can only achieve them under immense effort (or not at all) and get low self-satisfaction from it and no satisfaction from the intermediate achievements. Their are several reaction to that, e.g., people set their standards lower. If this is not possible, they drive themselves towards those goals, ruthless towards themselves. Another reaction to overambitious standards is to apathetically stop doing anything, because they cannot fulfill their standards anyway.

In the story, Sally's control loop gets disturbed by the environment at work. While she is motivated to collect health points, her work environment does not respond with rewards. Her co-workers are not taking part with comparable amounts of effort and the company wide health points are decreasing. From self-regulation theory, we can assume that the motivation will not continue for long, and she will change her actions.
In case of Theresa, her motivation for yoga and physical self-improvement is at its lowest. She does not feel able to fulfill standards given by the dresses environment (counting steps, etc.), so she discards the everyday usage (action). Also, she does not fulfill standards in the yoga group. Therefore, she does get negative feedback, and reacts with withdrawal as far as she can (self-comparison), hindered only by the obligation to receive the insurance bonus.

Self-regulation theory shows, that the human functionality, which is influenced by feedback from quantified self devices, has its vulnerabilities. Those can also be triggered by the devices. Hence, the assumption that continuous feedback leads to self-improvement and better lives for everyone seems simplified and can harm individuals.

In the self-regulation loop, falling short on personal standards does not lead automatically to actions of improvement and behavior change. Humans can use other techniques to do one thing, despite aiming for different set of standards. In [17] this is shown for moral standards. Typical ways to prevent feeling bad from failing standards, can be done by reinterpreting actions, effects, or blame so that standards are not perceived as failed. In the following enumeration, we use a failed standard as example ("too few steps on the daily counter") and illustrate with them how those excuses can look like.

Justification: People justify their behavior by explaining it in a purposeful, standard-attaining way. For example, "I didn't accomplish my step count today, but its fine. In the beginning its more healthy to not overexercise, anyway"

Palliative Comparision: Comparing the own achievement to something much worse, so that the own accomplishment looks better, e.g., "Most people never do sports, today I totally did half of the daily recommended steps".

Euphemistic labeling: Coloring the achievements in positive words, e.g., "I took a massive hike today and achieved a huge proportion if the daily recommended step count"

Displacement of responsibility: Responsibility is shifted towards other people, things, or authorities. "I couldn't achieve my daily stepcount, because my mum made me repair her printer".

Diffusion of responsibility: The connection between action and result is confused, e.g., "The daily steps are never counted correctly, the device is broken"

Minimizing: Avoidance of acknowledging any sort of harm or negative effects "It isn't that bad, that I didn't achieve my daily stepcount, I nearly did it."

Ignoring: Doing nothing and saying nothing.

Misconstructing the consequences: Disbelieving and discrediting harmful effects, e.g.,"It is not true that people even need exercise. It is all just a lie of the economy to sell us useless crap"

The following two examples are special and work only if there are human victims.

Attribution of blame: The victim is made responsible for the wrongdoing, e.g., in case of harm from devices (or software): "Why did she use the device in first place? She should have known better."

Dehumanization: Caring of other people is based on comparing oneself with them and putting oneself in their shoes. In dehumanization people strip others of their human characteristics, so that they do not hurt somebody "comparable". For example, "They are just consumers. Money givers. They do not want to think about their own goals, they just want to be comfortable. Let us tell them what they need to feel comfort. Next year, we tell a different story, and they will buy something else. How they really are... who cares?"

In general, people behave more according to their standards, if they feel responsible for the outcome. Both, excuses and self-efficacy, place responsibility and this is what makes them crucial for the self-regulation control loop. Thereby, self-efficacy can work positively within the control loop, but excuses avoid honest self-judgment and behavior change. For quantified self devices and for development of technology in general, the loop of self-regulation shows starting points for influencing people, to make them act according to the device, to "domesticate" them. Quantified technology aims at setting standards, influencing and monitoring the users actions. The feedback from the device then elicits feelings and other actions. Since the regulation loop can spiral out of control, developers and devices need to be sensitive to that. Some responsibility is needed, not to harm any users. Also, there is reason in the excuses people make for themselves. For example, people help to hold up a positive self-image and with it self-efficacy even if they fail. People can stay functioning, because they make excuses. Trying to strip that away from users by confronting them with allegedly measured truths, can make them feel shortcoming to their goals and then give up, as Theresa does in the story. Responsibility during development of quantified self devices is even more important because devices do not give always correct feedback but visualize only a small part of the picture. Self-regulation theory helps to find a fair use for users, because possible risk can be foreseen.

5.3.3 Self-control

Self-control is a special case of self-regulation [64]. It describes the human ability to temporarily suppress impulses and therefore control feelings and behavior. The immediate resolution of uncomfortable situations and the need for immediate reward is delayed and

accept to achieve a bigger goal. People with the ability to delayed gratification [57] are shown to be more successful accomplishing goals. If this ability is too strong, people become inflexible in their routines, even compulsive, and might even start ascetic lifestyles. If peoples have little self-control they tend to act according to their immediate stimulus. If something bad happens, negative feelings cannot be tolerated and need to be resolved as fast as possible. Typical mental health problems resulting from unbalanced self-control are eating disorders and addictions. Furthermore, people with little self-control can be more easily manipulated in comparison to people with mature self-control. Under pressure they will work hard to relieve the pressure, if they can, and lured with stimuli, they will more easy give in to their reward.

Effects of self-control can also be found in the story. Theresa shows signs of excessive self-control in her background story, when she lost much weight due to sport and deficient diet. She was only interested in slimming herself until she got sick, and has now problems participating in the yoga course. Sally has a functional self-control level. She uses the devices to exercise it by getting herself calm with meditation. On the other hand, she still reacts according to her personal feelings, despite pressure from her devices, e.g., she finds a way to get caffeinated coffee with the help of her co-worker, even when the devices classified her as overly stressed.

Self-control has two kinds of impact to handling of quantified self devices. On the one hand, people with fewer self-control can be more easily manipulated. A certain level of self-control helps to handle devices in a healthy way. Since people with low self-control are more easily manipulated, reliance on these devices is heightened, hence the companies' gain from these people is higher as well. Human-computer-interaction design, as well as big data algorithms would adjust themselves to influence those people. In the long run, technology emerges which exploits those weaknesses, i.e. low self-control. Since self-control needs to be learned and trained, this can turn into a feedback loop. For people with low self-control it would be more beneficial if they would learn to control themselves because it promises more success. Instead, technology like quantified self devices teaches users the exact opposite of being controlled externally. Gamification approaches or rewards for achieving daily step counts, reward in short-term what without devices would only be rewarded in long-term. Even if some might argue, this way they help to achieve the long-term goal more easily, people are trained to short term gratification, hence it would become harder to obtain long term goal outside of the gratification loops. If people are not trained in self-control they might further search for help in external short-term gratification as provided by quantified self technology. This amplifies the problem fur-

ther. Theresa's excessive exercise phase is unhealthy self-control, because she hurts her body in the long term. The satisfaction from excessive exercise and the current number of steps is short-term and is more important than her health.

In this section we saw that gratifying short-term goals by devices does not necessarily improve self-control even if it might look like it at first. Instead, it can improve domestication of users by devices and strengthen the dependence. Different design approaches, besides gamification and rewarding short-term goals, might be better for sustaining self-control and autonomy of users.

5.3.4 Feedback Intervention Theory

Feedback Intervention Theory [41] describes the effects feedback has on its receivers. It specifies which reactions the comparison between own goals and actions, the self-judgment in self regulation theory, can be elicited from individuals. Since quantified self devices rely heavily on feedback over activities of users, this theory gives insight for the development and usage of quantified self technology, to what extend the anticipated behavior change of users can actually be expected. Further, it shows, a possible outcome, if the behavior change user story is unsuccessful. Also it shows further influence on users beyond the scope of current device usage.

Feedback intervention theory states, the effects of feedback depend on the kind of feedback, the receivers themselves, and the task the feedback is given to. In one third of all cases feedbacks tend to worsen the performance of receivers. In two third, performance maintains or improves. This objects the assumption about quantified self devices, as our dress, that providing seemingly neutral feedback helps to improve the performance on a specific task. In case of the dress scenario, it can be expected one third of all users to not accomplish their daily step count goal, their level of calm, or their healthy eating habits. Theresa and Sally's co-worker are examples for that. Reasons for noncompliance can differ greatly and depend not only on the devices, but on the persons and their environment. Due to the uniqueness of lives, compliance to devices cannot be expected and noncompliance can be completely healthy as well as it can be based on excuses (compare Section 5.3.2).

For receivers, feedback can either reveal an achievement of a predefined norm or standard or a gap between those. The standard itself is a sum of weighted expectations of a persons internal and learned standards which were acquired throughout their live (comp. Section

5.1.1). If a gap between standards and feedback is revealed people act in one of the following ways: They can either change their behavior, change their standard, abandon the standard or reject the feedback. Only the first option can improve performance.

Feedback can shift attention from the focal task to either upper or underlying layers in the hierarchy of standards. Attention to lower layers can help maintaining a level of performance, but also runs the risk of achieving simple tasks, while not overseeing the whole point of the task, and to a lack of creativity to achieve it with a more sophisticated strategy. Also the shift of attention towards overlying meta-tasks can impair performance when it raises anxiety and competes over cognitive resources of the receiver. The shift towards meta-tasks can also lead to abandonment of the focal task, because the meta-task can be achieved in a completely different way more efficiently. Furthermore, feedback tends to focus the attention towards one central task, and side cues are disregarded. This further impairs creativity. Nevertheless, feedback can increase motivation on a task. But motivation only helps with performance on simple tasks when few cognitive resources are needed. This happens because motivation increases effort. If effort alone does not suffice to close the performance-standard gap then the attention is shifted towards another layer in the hierarchy to improve. If this happens, the performance tends to impair at first because new strategies are tried which aren't necessarily effective. Switching tasks on different levels of the hierarchy is used to find suitable solutions for problems. So switching of strategies needs creativity, which is impaired by feedback, and even if tasks are switched, they do not necessarily lead to better performance. This is is why feedback does not necessarily lead to better results.

Here we see the problem with the dress scenario. The feedback of the dress switches the attention to the lower layer of the standards hierarchy, to pre-defined solutions of the health problem. Using steps count, yoga (or other) courses to improve health are decisions on upper layers of the hierarchy. Theresa and Sally cannot freely switch those courses. The motivation to do more steps might be increased but to find happiness (meta-goal) in other ways is impaired. Theresa and Sally cannot switch because of the financial risk. But even if they would have the freedom, the focus on tasks like steps or yoga courses would reduce the mental space for creative thoughts as not doing exercise at all, or other solutions for the problems.

In the end, feedback is most promising, if it is used on familiar tasks, contains contentwise information that supports learning (not just numerical feedback), directs the attention to the feedback-standard gap at the task level and avoids cues that direct attention to

meta-tasks. Also, if receiver set their personal goals, the chances on better performance improve. The dress implements this partly. Attention is directed to simple goals, as the number of steps. The numerical feedback, but also the colorizing feedback, could be improved by giving more differentiated and context sensitive information. This would stimulate creative new ideas. But, integrating context sensitive information is difficult for technology as described in Chapter 4.2.3

Other effects of feedback are that positive feedback has the same negative consequences on performance as negative feedback. Praise can lead to abandonment of tasks as well as negative criticism. If the feedback is negative, and the receiver acts on it to improve the performance, the *velocity* of improvement is critical to maintain working on that task. If insufficient improvement is visible to receivers, they tend to abandon the task. This is important for the development of feedback devices. If abandonment of devices is not only the result of bad feedback but about feedback altogether, then developers cannot optimize it that much by giving better feedback. The whole concept of giving feedback via devices can be questioned.

5.3.5 Mirror and Chilling Effect

The mirror and chilling effects are two further effects which can elicit behavior change of individuals and strives the usage of quantified self devices. The mirror effect [32], similar to feedback intervention theory, can lead to behavior change. Experiment in [32] showed, when a mirror is placed in a room with single individuals, they change their behavior towards acting increasingly according to their own moral standards, as a form of increased *private self-awareness*. In contrast, *public self-awareness* appears, when people feel observed by an audience. In this case, they tend to change their behavior due to their expected exceptions the other participants have on them. The second is also known as the chilling effect.

The chilling effect, as part of the public self-awareness, appears when people feel observed. Then, they are scared away from actions which seem adverse to the perceived expectations of the audience. This can also be caused by audiences, which located remotely but included in the users life over proxy technologies. For example, Facebook users [47] are “chilled away” from appearing in photos in a way their facebook audience would disapprove. This leads to *impression management*, which is offline behavior to manage the online impression of themselves, e.g., by telling people not to put images

on Facebook, hiding drinks or rejecting Facebook connections. All of this comes with increased mental effort to repeatedly think about their online audience while being offline and acting accordingly. As a result, users tend to allow only the smallest common subset of information about them online, which avoids negative impression to anyone of their online audience. In contrast, there is also a "warming" effect of people trying to be or appear more in positive light towards the audience [47]. This can act as motivation to do good things, e.g., taking part in charity events.

This shows which kind of motivation can be expected by observation through quantified self devices. Users act motivated by fear of social disapproval and according to their impression management. It leads to several problems. Quantitative measurements of physical bodies and behavior are difficult to beautify. Users feel the need to beautify their impression, and seemingly contradictory, at the same time, aim for neutral feedback about their accomplishments. The difference is the kind of audience. Users might risk a look at "neutral" data privately for themselves, to improve themselves (as in the mirror affect), but for other people, users try to act in reference to the audiences standards. Users do not want collected "neutral" private data, to be seen by other people. It reveals unadorned "truth" about themselves.

In the dress scenario there is no difference between data sent to agencies, seen by other people in the yoga course, and used only for private feedback. This can easily result in bonuses being cut and bad societal impressions. There is only a small range for impression management, in so far as people can decide which data can be shared, or not shared, but not what the shared data looks like. Further, the monitoring creates strong motivation to live a private life according to social, or other pre-given standards. This effect is constantly affects users of the dress and impacts their feelings of privacy and behavior. Developers of quantified self technology should be aware of that. The price for the reduced privacy and impression management opportunities can impair self-development and even democratic processes as described further in Chapter 6.6.

5.3.6 Transtheoretic Model

The transtheoretic model (TTM) ([25] after [51]) describes how intentional long term behavior change is achieved. For quantified self technology this is important, because it shines light on what users go through to actually change their behavior, either to choose a quantified self device or not, to use it or not, how the change of behavior happens and

in which stages of behavior change devices influence users. In TTM people go through several stages to establish a new behavior into their lives. *Precontemplation* is the initial stage in which an old behavior is executed and no intention to change is made. During the *Contemplation* stage people feel a little bit of intention to change their behavior someday. In the balance between advantages and disadvantages the disadvantages still win. Thereafter, *Preparation* stage follows. People prepare for behavior change by obtaining more information about the advantages, and making plans to change in near future, or even make small attempts of first changes. In the *Action* stage, people implement the previously planned new behavior into their lives. At last, follows the *Maintenance* stage during which the behavior is adjusted and solidified. This last stage continues. Behavior change is a long term process and requires daily attention and practice. During the process regression to prior stages is normal and also that those states overlap.

An example for behavior change is Sally changing her breakfast into a healthy one. A transition can look like this. At first she does not have any intention to change her breakfast style (Pre-contemplation phase). Then she gets motivated, either by the device or other information as targeted advertisement or health brochures. She starts to compare herself the standard of society, or companies, or audiences who monitor her health status. She thinks about changing her eating habit, and maybe to try a healthy breakfast one day (contemplation phase). In the preparation phase the motivation to act increases. Maybe she thinks herself now, that it might be a good idea to live healthier. Another reason could be that eating healthy was simplified or made more attractive for her, maybe she informed herself and found out, that eating healthy has beneficial consequences. She searches for healthy recipes online, checks out prices during her grocery shopping and makes a plan in which combination it could work for her. The following Monday, she eventually buys healthy food and on the next morning she uses it (action phase). Now she enters the maintenance phase. Here arise complications whether she enjoyed the particular meal, which ingredients could be changed next time, which quantity of this food she needs in the morning or contemplates how to diversify breakfast experience.

During the stages the retrieval of new information and insights can encourage the transition from one stage to another. Those are *Consciousness raising*, *Outcome Expectencies*, and *self-efficacy*. *Consciousness raising* ([25] after [24]) describes awareness towards a problem and its surrounding conditions and ramifications. This can either happen by new, prior unknown information (e.g., Sally sees advertisement for healthy breakfast and sees that her current breakfast is not among it) or by enhancing the problem of one of its effects (e.g., Sally's old jeans do not fit anymore, she reads an article about diabetes,

or buys accidentally healthy food and receives positive feedback). Consciousness raising helps the transition from precontemplation to contemplation stage in TTM.

Outcome Expectancy [25] is determined by the balance between the advantages and disadvantages of the current and the idea of the new behavior. This plays a role during precontemplation and contemplation stage of TTM. Eventually, the advantages outbalance and the transition towards the next stages is enabled. In the beginning, Sally needs to get convinced that eating healthy helps with her goal to stay healthy, become thin, or get a clean skin, whatever the individual goal is. Otherwise she had no reason to try a different life style. Similar, when she does try meditating. She believes that it makes her calm, and the dress gives her positive feedback about it. The latter is also an example for the workings of feedback during an maintenance change. Other feedback about healthy food can be given over health points during purchase, over change in body fat percentage (i.e. measured with scales).

Here we see several entry points for modulation of behavior. In the first phases, information is key. Feedback from a dress alone can maybe show a problem, but its hard to direct the user in any direction by itself. Working only with quantified results as feedback would need a try and error approach to optimize the situation. So in the dress scenario, the feedback of the dress is supplemented with commercial advertisement to direct behavior change. So we see a mechanism where feedback and information open up searches for solutions during contemplation stage and also providing several solutions. The providing of several solution during the preparation stage is the second entry point for modulation of behavior. This kind of manipulation, as the interplay of need and solution, is long-established in advertisement. The new aspect of quantified self technology is that it is so much more privately connected to the user. The need is created by pre-thought goals, e.g., the default of daily steps. Needs can be influenced more directly. For example, an update on the dress changes some default goals, the feedback changes slightly, and more solutions are searched for by potential users. Creative, autonomous, and individual solution searching for problems of health and wellbeing, is prone to be replaced by default solutions which are entry points to exploitation by commercial entities.

6 Ethical Reflections

Ethical reflections about technological developments are rarely found during technological development processes. Only in the last years, human-computer-interaction and ethics were increasingly introduced to curricula of computer science. At the same time ethical values in computer science gained attention of media for certain topics as data protection or driverless cars. The attention was gained because the effects, if these technologies fail, threaten lives and democratic values quite obviously. But technological development does not need to raise life threatening risks to deserve attention for its ethics. As we saw in the previous chapter, technology immersed in every day life changes users. The technology introduces small risks, and small value transgressions. Over time small transgressions of those values become normal, people deal with it, and adjust to the consequences. Thereafter, larger transgressions are prone to be accepted because they look like small ones. Thus, technological advancement needs to be value sensitive even on a small scale, otherwise, they can evolve into larger risks to peoples happiness. To prevent this, developers of technologies can check, in all conscience, which effects their devices or software actually have. Since it takes a lot of effort to do so, the incentive to just ignore the topic and pushing the responsibility for the usage to the users is quite large.

Ethics is the theory of morals. *Moral* norms are value based guidelines for human behavior, which include ideas how people should live together. Not all moral norm fit to each other, but they can contradict, and therefore use justification to provide validity. For examle, some people think it is alright to eat meat, others object, and all people have their justification for those moral norms. In contrast to moral norms stands *ethics*, which is the science about all those norms, justifications, ideas, and the validity of all of these. Moral norms are important for societal cohesion. They describe rules of behavior that enable coexisting. A basic example for this is the rule not to murder fellow human beings. If everybody in a society lives by this rule, everybody in the society is safe on the most basic level on the bottom of the pyramid of needs, physical living. Ethical rules like this have to be distinguished from law. Laws can include highly unethical regulations,

they can also ensure some kind of cohabiting, by they can exist without being ethically justified. Ethical behavior of a group of individuals enhances the chances for a happy living by not mutually harming others. Therefore, developers of new technology need to take on the responsibility not to harm their users or the society with their inventions. Users and society pay the price for inventions that transgress moral values. An obstacle to create ethical technology is that ethics, philosophy and psychology is not common knowledge among computer scientists. Many computer scientists seem to hesitate to enter the topic, unless it is commonly discussed in computer science scene, as, for example, security and privacy issues. The good thing about ethics is, that it is not that difficult to build moral opinions. The first step is getting to know the topic from as many sides as possible, compare it to the own high level standards and values, and then form an informed opinion [35]. Everybody has the right and also the responsibility to do this. As described the part about standards and goals (Section 5.1.1) transgression of goals and values are palpable, so people can actually 'feel' their values and form their moral standpoint about that. A challenge is, to get enough trustworthy information to create a mostly comprehensive picture. Ethical judgment develops over learning of new information, so things which were felt to be justified several years ago, are not considered fair anymore because of additional information. In Hoerster's approach [35], a ethical norm is justified, if it benefits a person considering all her interest in her weighting of those, and when a large proportion of people also benefits from this norm. The second part is the prerequisite to gain validity from a society.

Ethical reflections base on values. Values are desirable characteristics of objects, ideas, and behavior. They are desirable because they help humans to flourish and become happy in their lives [56, Chapter 4]. Values have different degrees of influence and generality. Some are shared under a large historical and societal consensus, for example health. Others are relatively new, and still questioned by a large number of people, for example the value of intact nature, or in case of computer science, beauty. Values can commonly be distinguished between intrinsic and extrinsic values. Thereby, extrinsic values can be ascribed to be part of other intrinsic values. Intrinsic values are values which stand on their own. For example the extrinsic value of privacy includes the intrinsic values of security and freedom. There exist a broad philosophical discussions which values are considered to be intrinsic or extrinsic, which we will not discuss here. Also there is a distinction between moral and nonmoral values. Nonmoral values are values which are considered to be desirable by society and state what is good for individuals to strive for. They are not obligatory. On the other hand, moral values concern how people act in

regard to other people and therefore include an expectation how to behave. An example for a nonmoral value is beauty, and a moral value would is responsibility. A critic about values is, that sometimes values are created which harm people, but are still followed by a society. An example for this was the value of Aryan descend in the Nazi regime in Germany. This means that values also need to questioned critically in their ability to harm. In regard to those abused values, we assume the values used in the following discussions are generally not harmful and have a broad consensus. We refrain from in depth discussion about the validity of individual values themselves, but we analyze what they contribute to the case of quantified self devices. In this section, the discussed values have a different degree in their generality, whether they are more intrinsic or extrinsic, nonmoral or moral. This analysis does not strive to get all values on the same level of abstractness, instead, it checks which values are touched or transgressed, and if its useful, we look which other values are included and how they influence each other.

The benefit for individuals is the baseline by which this chapter justifies judgment over quantified self devices and proposals to improve such technology. To achieve this, the effects of quantified self devices need to be analyzed. We see technology affecting and influencing humans in three different dimensions. Each dimension is its own system of functionality and has different sets of challenges and risk. The *personal* dimension includes all impact on users in direct contact with the device. The influences related to devices and third persons (or a set of third persons) we call *interpersonal dimension*. This includes how other persons see users through devices, or which kind of impact third persons have on the users. The last dimension considered is *infrastructural*. This includes every physical infrastructure change as well as more abstract systems as democracy or economy. These dimensions influence each other, but also have their own inner workings. The analysis in this chapter focuses strongly on the personal dimension, and bases on the insights of Chapter 5. Effects from the infrastructural dimension are mainly considered in the sections about responsibility, paternalism, privacy, and justice. The interpersonal dimension is not heavily focused but occurs in the sections in connection with Sally's workplace experience.

This chapter reflects effects of quantified self devices and their benefits and risks. The goal is to find out what ethics in technology means and in which ways quantified self technology can benefit or harm humans. For this, we examine the scenario for certain ethical values and how they are influenced by the effects quantified self devices have on users. Next to analyzing given situations, we propose alternative approaches to improve the situation insofar as values are maintained or created. In the last part of this chapter

we summarize value sensitive design approach, which is an abstract design approach for software development which considers ethical concerns of users. This chapter follows a best afford approach by reading material and interpreting it for the case of quantified self devices and drawing conclusions. It is an attempt to form a moral opinion, based on information from reading, reflecting, talking to people, and thinking about what other peoples standpoint, with other prevalent values, might think. It does not claim to be comprehensive and complete. Instead, it takes a stand to start a discussion.

6.1 Choices and Knowledge

This section about choices and knowledge starts the ethical reflection over quantified self devices. Freedom and knowledge are the basis for pursuing personal goals, e.g., those in Maslow's pyramid of needs (compare Section 5.1). Choices represent freedom in the following work because we see them as concrete implementation of the value of freedom. The choices someone has, determines how free the person is. Information is the basis for freedom and choices, because only with information, knowledge and transparency over expected results, informed choices can be made. People use their choices to fulfill basic needs, as in Maslow's pyramid, as well as additional virtues from self-actualization stage (e.g., beauty, fame, harmony, pleasure, exiting life). The overall goal of peoples choices is personal welfare. In this section we reflect how knowledge, personally or technically created, interact with choices, and which risks and benefits emerge. Choices do not only reflect personal goals, but are also influenced by interpersonal goals, and incentives from institutions. An example is the motivation to use quantified self devices, as the dress. The choice is influenced by personal values, by communal motivation and by incentives from agencies.

Choices base not only on information but also on knowledge. As shown in Section 4.2.4, knowledge is created from elaboration and learning of information. The definition of knowledge itself as knowledge, consist of three different aspects [56, Chapter 5]:.

1. The facts on which the knowledge is based are not allowed to be wrong.
2. Knowledge needs a *beholder*, who *knows* it.
3. Knowledge needs truth, because "wrong" knowledge is not knowledge.

If one of these things is not fulfilled, the examined object is not knowledge.

Respectively to knowledge creation process (comp. Section 4.2.4), in case of quantified self, raw data can convert to knowledge in the following ways. The *facts* of point (1) from the definition, is the sensor output and other tracking tools. To create meaningful knowledge in the end, those tools must work correctly, appropriate to the situation. Also, according to point (3), the interpretation and elaboration of data, must work correctly. This includes, that the chosen sensors and processed information are the correct ones to produce the desired knowledge. The *b*eholder (2) of the knowledge can differ. Of course, users can learn from information, which is represented to them in an interpreted way. So users can be beholders. Also institutions like health insurances and companies who run those devices are hold knowledge. At last, we define also technical system itself as beholder, to the extend information can trigger effects. The non-transparency of these decisions make them a knowledge holder from the perspective of users. As a side note, even developers have problems knowing how specific results or program states are created or "learned" by systems, especially, if the responsible algorithms are self-learning ones. So we consider certain black box technology to hold knowledge.

On the way from raw data to knowledge, many failures can emerge, so that no "true" knowledge, due to its definition, is created. Knowledge or information which is not correct with regard to its definition is hereafter named "wrong knowledge" and "wrong information".

If the measured data is wrong, to the extend that recorded data does not represent reality appropriately, and information and knowledge created on it, is also wrong. Recorded data can be wrong because recording does not work on the technical side, because the data set is biased, or because "assumptions" are made during the development process and included as some kind of fact into the devices. The latter can be assumptions over the world or the users, e.g., in form of user stories. Computed results, information or knowledge, on the basis on wrong data, would lead to wrong assumption about the world or the users themselves. Furthermore, standards and goals implemented in devices can be regarded as facts according to point (1) of the definition. If these standards are wrong, e.g., a standard is not helping as promised, users would learn the wrong things. If wrong facts about the recording of current achievements is noticed by users it can lead to frustration, or rejection of the device. An example is shown in Fig. 6.1. Herein, users complain about the a tracking device not recognizing their exercise. One of the comments mentions the replacement of the device because of this. This is a result of

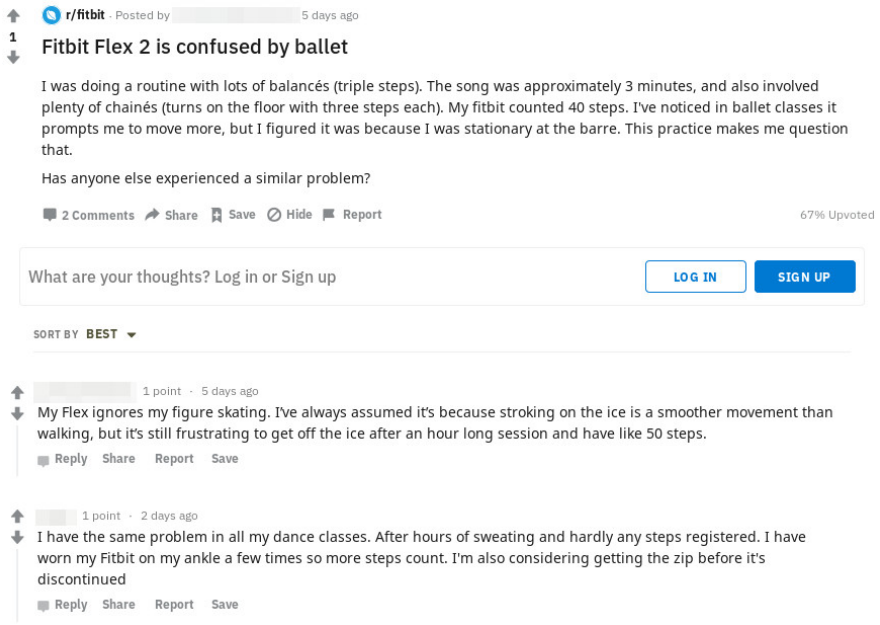


Figure 6.1: Example from real life how information is wrongly measured, and the frustration of coming from it.

wrongly perceived basic data. The same commentator as before tried to wear the device on the ankle to make it work better, which. This is an example of domestication of the user by the device. Changing the kind of exercise to fit better to the device would be another one.

Also, the interpretation of correct data can be wrong. In this case, also the feedback given to users does not fit to their current state. If users would believe the feedback over their own experience, they would think that themselves did something wrong. For example, if somebody has a high pulse and sweats a lot for some kind of illness, and devices interpret it as stress and nudge them to calm themselves down, it won't work. If the device is believed, then users might think, they themselves are unable to calm down and responsible for their own bad results. If they figure our that the device was failing, they can either ignore the result, if it does not matter to them. They can reject the device, because it does not kept its promise, or they can use it in a completely different way. An example for the latter kind misinterpretation of data is the notion Sally receives about her "having a cold", because she has higher temperature because of her upcoming menstruation.

Also knowledge creation by learning can include failures, even if both, data and informa-

tion are correct in an appropriate way. Wrong knowledge from learning from a quantified self device and its environment could like this: some users are *often* sick, so their lifestyle must be unhealthy. This would lead to an expectation of users to improve their lifestyles. The notion, that they are sick might be correct, but the interpretation of "often" is easily biased. Imagine a women lives a life, which is sorted in a "masculine" group by a classifier, for example, because she works in a male dominated field, and also plays male dominated sports. Her own increase temperature of menstruation cycle would lead to comparably many "sick" days. This does not mean, that she is sick, or her lifestyle is unhealthy. It would be just an error in the learning and comparison of the algorithm. This kind of error is distinct to biased raw data, insofar as this can also happen, when the data is not biased, but the algorithm classifies it wrongly. In learning algorithms, the coherences are not comprehensible by humans anymore because they base on so many different recorded features. The algorithms are designed to find more coherences than humans could. So its contradictory to demand full transparency. Interpretation and learning from technical point of view looks very similar, an algorithm interprets data. If that was done by machine learning algorithms, is of secondary concern for the technology. For users it makes a difference, insofar as they can either make sense of what is going on, and whether they have a feeling whether an information or decision is justified. Information, as interpreted data without machine learning algorithms, can be shown in ways that user perceive them as understandable, results on the basis of learning, not necessarily. Furthermore, also a users as beholder of knowledge, can learn wrongly from presented information. They can learn to overexercise because they think, the more, the better. They could learn a wrong image about their own achievements.

Of course also on multiple steps on the way between data to knowledge failures can occur. This would lead to unforeseen consequences and would render devices probably unusable. Also, wrong data, or wrong information, cannot lead to correct knowledge in the next step.

We saw that wrong data, information and knowledge can work adverse to the users needs. But how can wrong and correct knowledge be distinguished? One way to achieve this is transparency. If every step can be understood and comprehended, people can decide whether represented messages, goals, or practices are expedient. This procedure of reviewing requires a lot of effort, which renders it not useful in many situations, especially for users. For knowledge created by algorithms, transparency, checking of results can either be done by humans or by a differently implemented algorithm. The correctness can be checked whether the second algorithm comes to the same conclusion, under the

premise that this second algorithm does not include the same mistakes. Both methods of reviewing are costly, especially since algorithmic knowledge bases on so many features, that it might not even possible to understand its coherences. Furthermore, the incentive to review results of learning algorithms, is low, since they are made to make analysis expendable. Therefore, users cannot know, whether knowledge, created by self learning algorithm is correct. If knowledge is created by users over feedback information of devices, wrong and correct knowledge can be distinguished by self-reflection and sharing thoughts and results with other people. In that way people can gain perspective. For check information of devices a feeling of "can this be true?" is also helpful. For example, it just fits not to human understanding of exercise that ballet or ice skating are not exercise, as shown by devices in the example above.

We saw that wrong data, wrong information, and wrong knowledge can be produced by the devices. But how big is the influence on users and the risk, that users learn wrong things? And how much skepticism is appropriate? At first we need to establish what a wrong thing to learn actually is. A wrong thing to learn are procedures or standards which do not support users in their autonomous self-development for a happy life. Respectively, the right thing to learn are procedures and standards which support users in their autonomous self-development towards a happy life.

The impact on users is analyzed subsequently with the help of the transtheoretic model, feedback intervention theory, and coherences between needs, satisfaction, and the risk of addiction.

Transtheoretic Model (hereafter *TTM*, compare Section 5.3.6) describes stages to change behavior. From defensive precontemplation stage, over contemplating possibilities, followed by preparation for change, the actual action to change, and the maintenance phase to hold on to the new behavior. Information and feedback crucial to advance through the stages. In early stages, information seeds ideas, and in later stages information and feedback convey images about progresses in the users actions. Also, the demotivating character of wrongly interpreted data, as shown in Fig. 6.1, takes place in the action and in the maintenance stage of TTM.

Information, shown to humans, can initiate change in people. Through this information in early stages of TTM, people recognize something about themselves as worth of change. This consciousness raising, is supported by information. If people are often presented with information to change, the probability increases that they eventually act on this extrinsic motivation and change. To follow through with this personal change, requires

a lot of effort from individuals. The question to answer in contemplating change by the individual is: Is it worth it? What does the effect eventually improve my lifes? Are the promised goals, which can be received by using this device really making me happier? These questions do not need to be answered literally by individuals, sometimes they can work unreflected by default answers. For example, people always try to make themselves "better" persons and will naturally try many ways to change. Other have just given up on ever becoming happy, and they won't change. Also, others think through the questions mentioned above and decide differently every time. Nevertheless, all of these decisions are choices, and therefore influenced by available knowledge, e.g., from quantified self devices.

Only individuals themselves can know (or find out), which goals in life make them happy. Nevertheless, many different kinds of information tell people all the time, what will make them happy. For advertisements, this is an old story. Therein, people are persuaded to buy new products, because they are somehow not "happy" enough. Quantified self devices, as the dress, take this to the next level. They are with their users 24/7 and remind them all the time to optimize themselves according to the algorithms. Therefore, the goal of having a healthy body is omnipresent, clings to the bodies at all times. Because of their closeness, it can easily establish precedence above all other goals of users, which do not have such a support machinery. For example, users are nudged to walk around, even if they are experience a flow state in their work in front of a desk at this moment. Flow states themselves are very enjoyable and increase happiness. It can bring people nearer towards their goals, and accomplishing things boosts self-efficacy. Nevertheless, the nudge, i.e. the informative feedback, of the quantified self device takes precedence by disrupting the user. One might argue, that people can ignore these messages because they can decide at the moment which action is best for them. Yet, the user has to *actively* ignore the message, which is especially hard if users are motivated to listen to their device. This happens when they identified themselves with the propagated goals and are already in action or maintenance state of TTM. Ignoring such messages needs to work against the psychological procedure of learning, while the device works in line with the learning procedure. It will be hard for users to constantly resist against this nudge.

The problem here is that extrinsic goals are pushed effectively via transmitted messages. Other, more personal goals still depend on the persons own unsupported capabilities. Furthermore, the attention towards the letter is easily disrupted by those devices. Therefore, extrinsic goals for health get a head start, in comparison to personal chosen goals

and standards. Maslow's pyramid of needs showed that personal goals are a big part of what eventually make people happy. This is one reason why usage of quantified self devices with active nudging and feedback capabilities act contrary to peoples happiness. Extrinsic goal can become prevalent and superimpose personal goals. Even if the chosen goal of the user would be the equal to the goal of the device, those goals would take precedence over other goals.

Another idea to reduce the prevalence would be to change the the functionality of the dress, so that it does not vibrate. This would not solve the problem. In general, there are many ways to get peoples attention. May it be by vision, audio, or any other sense. All of them have the capability to be intrusive or unobtrusive. The problem lies more in the level of obtrusiveness and quantity of specifically aimed messages. So, whether its tactile feedback or other, does not matter for the described problem. Unobtrusive feedback is more polite, and respects peoples decisions what to do with their time. But they would not be as effective, as real time feedback. They would also require more incentive by the user to actively look up their results.

In Section 5.3.4 about feedback intervention, the impact of feedback on people was shown. Feedback of quantified self devices is information, which users learn from and from which they plan their next steps. We saw that the velocity of improvement is crucial for people to reach their goals successfully with the help of feedback. If improvement is too slow, or the challenge is perceived as trivial, people tend to not improve or receive even worse results because of feedback. This is another way, how wrong interpretation or depiction of data by quantified self devices can impair the improvement of users. Comparisons with societal standards or comparisons with older data can also have these effects. Also, since everybody has different talents, it is unfair to compare achievements in this way. Users with intrinsic motivation, who are successful to begin with because they maybe did the same exercise before, can be distracted from what was fun, and reduced to pure numbers. In other cases, people with experience would receive unsatisfactory results, because their is no challenge for them. There would be no reason to put much effort in. Improvement is something people would expect to see in graphs as some kind of steadily increasing curves. But this is not what learning looks like. People try new things, get temporarily worse with their results, learn something new from it, and then make three steps forward. The two-dimensional curves and results, reflecting the velocity of improvement, cannot reflect the multidimensional heterogeneity of learning. Tracking reduces this complexity until it looks like success or failure in two-dimensional curves, even if the failure was a success for another goal of the individual. The natural response to getting temporarily

worse feedback would be negative feelings. The feedback would also lead to focus on lower layers in the hierarchy of goals and standards and to disregard of side cues. This also impacts peoples happiness. People need to switch between layers of the hierarchy because step-by-step learning and deciding on a meta-level what to learn influence each other. If people notice, an activity does not lead to the desired result, they need to reflect about the situation and find another way or another goal. So, learning can be impaired by the reduced complexity of feedback and the focus on simple tasks. Learning is also essential for people to make themselves happy. Thereby, accepting and supporting feedback can people make feel good about themselves even when they make mistakes, which are essential for learning. The reduced complexity of feedback graphs does not provide this.

Pre-defined user stories also do not provide the environment for free experimenting and learning. The goal to cover many goals and user stories on different levels of the goal hierarchy is expensive. Companies would try to minimize the cost by implementing devices, which fixate people on one user story and convince them to stick with it on lower layers of goals hierarchy, than actively supporting autonomous goal changing. This means, that with this kind of self-optimizing user story, which does not support autonomous goal changing, and economic incentives of being bound to devices, is in itself contrary to peoples happiness. One might argue, that it is possible to implement many user stories, and that many different kinds of feedback can be supported by devices. Also, self-learning algorithms could support users in their individuality. It could be also seen as a gap in the market to support all of this self-development within devices or applications. But this is not going to be successful. There will always be the point, when users need to act out of the predefined user stories and experiment with different kind of live choices. Not "everything" can be included. Human creativity can create a many more possibilities than computers can. Self-learning algorithms cannot to actively support users individuality with their feedback, because algorithms learn from *past* data (by one human in case of individualization, by many people in case of classification). In contrast, human learning and self-development is based on looking *forward*, hoping, dreaming, and experimenting creatively. This cannot be done by algorithms, or any other computer based invention. Hence, the narrowing of thinking by feedback of those devices impair the users self-development to happiness.

Theoretically, from the design and technical side, user stories could include the discarding of devices and support autonomous decisions away from the device. One could imagine user stories declaring the devices work done, or a device slowly drawing out of the control

over the user. This would be preferable in comparison trying to hold on to people as long as possible. This could be even a market. But many problems regarding feedback would still exist. Feedback would still be based on past data, would not lead to improvement for one third of all users, decision when to draw out of the users live would still be based on user stories, and creativity would still be impaired. Nevertheless, a broader degree of freedom could be achieved, and it would not impair users ability to make themselves happy as much, as with the status quo.

Feedback affects motivation, too. We saw, in feedback intervention theory, feedback itself leads to concentration on one task and can also increase motivation to achieve it. There also exist a more fundamental kind of motivation. In Maslows hierarchy of needs the four lower needs need to be fulfilled, otherwise humans feel strongly dissatisfied and are highly motivated to fulfill them. Those layers regard physiological needs, safety needs, relationship needs and esteem needs. We also saw, how feedback from devices can contribute or impair feelings of self-esteem. Here lies the risk of addiction [66]. Humans can develop needs of positive feedback from their devices to get the feeling of overall self-esteem and self-worth.Such an addiction would maybe depend on achieving specific feedback from devices every day. Users in such a situation can start depending on the positive feedback, when insufficient other sources of self-esteem are available. This kind of resolving of dissatisfaction plays a crucial role in addiction [66]. Furthermore, feedback can also impact self-esteem negatively, so that it is able to further contribute to the problem of low self-esteem, at the same time, as it used to resolve the problem. The resolving of self-esteem problem, e.g., by achieving specific feedback, would also be temporarily and not resolve anything, which is also typical for addiction. So in quantified self lies the risk of addiction. In our story, we saw two different effects of motivation. For Sally it works in a healthy way. She becomes motivated and achieved positive things. Theresa instead overdid the step counting and weight loss. This could be a consequence of such a kind of addiction.

So information from quantified self devices can cause or contribute to a many problems. For humans to be happy, it is important to decide over their lives on their own. These decisions base on information. Therefore, failures in technological information processing influence those decisions. For autonomous humans, under the goal of making themselves happy, it would be important to reflect of their current state happiness, and whether their current actions are working out. But this reflection, is what information from quantified self devices influence. Therefore, it influences the the actions people choose on the basis of those reflections and therefore the way in which people try to make themselves

happy. This can happen in many ways, from wrong data tracking, over interpretation failures, over changing of users focus on tasks, over reducing autonomy by reducing the flexibility to change goals and tasks, to the choice of next actions and possible interplay to addictions. These things show errors which can happen and users would need to detect those in order to help themselves. But Users would need a different kind of reflection to do this. They would need to compare the results from their devices to their own personal experience and decide whom to believe. This is difficult in itself when two kind of as equally regarded information contradict each other. It is further impeded when results of those devices are regarded as neutral and objective and their information is considered superior to the perception of the user. With those devices humans are trained to *not* listen to themselves, their inner voices and their bodies, but this is exactly what is needed to work against the mentioned problems from the feedback quantified self devices.

A lot of skepticism is reasonable during the design and usage of quantified self devices because the knowledge and feedback can be faulty or do not fit sufficiently to individual persons. The price which users pay can be quite high. Usage reduces the autonomy, it changes self-perception, and it can act in sync with addictions. The technological side of those devices cannot compensate those risk because they cannot calculate individually right things before the users themselves do. Nevertheless, users need to be supported in a way which includes their true learning experience. The users autonomy needs to be respected, because it is a basis for happiness. And also, knowledge from devices need to be met with healthy skepticism instead of anticipation of neutrality and objectivity.

6.2 Trust and Control

Trust and control define two sides of a coin under the same goal of protecting people's vulnerabilities. In this section we take a look at the of the nature of trust and control and its interplay. We examine the distribution of trust between users and devices, between different user, and in the user-device-developer relationship and analyze their ability to help people climbing up the hierarchy of needs.

Control is the action or the opportunity for an action which causes change. This includes the non-acting also causes a different outcome. For example, if people would have the control over the sun rising in the morning, they would need to also have the power to not letting it rise, otherwise they would not be in control. Proving that they did it, with their action, would be different discussion about scientific proofs. We can differentiate

between three different kinds of perceived control. Causal control is when the action is the logical reason for the result. In this case, every execution of an action results in a specific result. This includes that steady environmental variables do not change. For example, people can have the control over holding something in the hand or letting it drop. The object will always fall down in an comparable environment, e.g., on a planet with gravity. People holding an object have causal control over the object being dropped on the ground. Also, they need to have the control to not letting it drop, otherwise it is not control. Another kind of control bases on heuristic correlation between an action A and its result B. If A is executed, a large number of times B happens. An example would be eating a lot of heavy food and having bad sleep afterwards. This enables to control over a number of actions similar A, to improve the quality of sleep, but does not guarantee it. It can be perceived as control if the heuristic correlation is large enough. The last kind of perceived control can happen, if action A and result B are not heuristically correlated. A and B appear randomly together. Nevertheless people can perceive it as some kind of control, because they believe A leads to B. This believe can even improve their happiness. For example, believing to be the cause of the sun going up in the morning does not necessarily make someone unhappy. Nevertheless, the reverse check of for the action will fail, or also only happen randomly. In this section we talk about causal and heuristic control and disregard illusions of control.

In [56, Chapter 5] control perception of users base on three different kinds of control. *Cognitive* control is the understanding of current situation, *decisional* control is having options to choose from, and *behavioral* control is giving opportunities to actually proceed with the chosen opportunity and feedback of the effects of the chosen option. All of these parts of control are based on information. Information forms the base for decisions to act or not to act, and feedback information acts as confirmation for executed actions. Within this, the number of different and independent sources of feedback increase the reliability of information and the feeling of control. Control is learned by experimenting with actions and evaluating the feedback.

Trust, on the other hand, is based on voluntarily accepted vulnerability. This can be the lack of information and feedback and still believing in a beneficial outcome for oneself. Trust can be placed in other persons, in technology, in systems, and in other things. It is the believe of humans that something beneficial will happen for them despite being vulnerable. Therefore, trust, similar to control, is context sensitive because in different situations and different actions, different levels of trust are placed or justified. Buechner et al. [21] states, humans are capable of entering trust relationship with technological

devices. Thereby, trust relationships are defined between two Agents A and B, which fulfill the following conditions [21]:

(I) A has a *normative* expectation (which may be based on reason or motive) that B will do such-and-such;

(II) B acknowledges that A has this normative expectation, and B is responsible for what it is that A normatively expects her to do;

(III) A has the disposition to *normatively* expect that B will do such-and-such responsibly

(IV) $A's$ normative expectation that B will do such-and-such can be mistaken;

(V) [Subsequent to the satisfaction of Conditions (i)-(iv)] A develops a disposition to trust B.

Hereafter, we call A the trustor and B the trustee. We see that trust relationships are bidirectional because B has the task to acknowledge the task placed in them. B's have the autonomy to deny it, which lays the foundation of the relationship part of the definition. Trust itself can also be placed in entities which do not acknowledge any expectation.

The definition leads to a situation where A's trust, which is placed on the trustee, defines a task for B insofar, as trustees are supposed to act in a beneficial ways for trustors. This is why, not only trustors but also trustees can feel betrayed. Trustees can betray their trustors by not acting in a beneficial way and leaving them behind to deal alone with their vulnerabilities. Trustors can betray their trustees by pushing an unwanted task to their trustees. For example, sharing the knowledge of a crime committed by the trustor. Trustors who share this kind of information may create a moral dilemma for the trustees. Should the trustee keep it a secret, maybe for the cost of a third person, or should the trustee tell the police and betray the trust?

Devices, as the dress, separate the trustees palpable sense of responsibility from the eventual executed actions. Users handle their devices and believe them to be a trustworthy entity in a certain context. Also developers are separated from users by the device. They also have more contact with the device than with the users. We argue that acknowledging responsibility is more difficult on the companies side when the users are far away and therefore the trust towards devices is often not justified. Users cannot know what happens with their data or which kind of nudging techniques are built into devices. Furthermore, companies usually do not feel the interpersonal responsibility for handling

sensible information or situations they would feel, if they were actually in front of the person revealing the same vulnerabilities. Since trust and control are both mechanisms to overcome uncertainty in situations while believing in a beneficial outcome, users are prone to either trust or control their devices, resp. certain aspects of them.

To justify trust and trust relationships, Buechner et al. [21] distinguish between trust and trustworthiness. Trustworthiness is the evidence based belief that trustees act beneficial towards the trustor. Trustworthiness is in most scenarios needed to *justify* acts of trust in trustees. Trustors need to estimate the trustworthiness of the trustee and adjust their trust request accordingly. In certain situations the justification does not need trustworthiness, based on prior evidence, from both parties. For example, if trustees need something to be done from trustors and have no appropriate alternative, it is justified to trust that entity even if no evidence for trust is given [21]. Justification is needed for trust, because it is what makes the usage feel acceptable, eventually, even if the circumstances are not perfect. Justification can also be achieved over the excuses shown in Section 5.3.2, and we see that justification and those excuses fulfill a goal to keep individuals functioning in less-than-ideal situations. Humans create their beliefs about trustworthiness and control over time. In case of trustworthiness, the acceptance of uncertainty is rewarded with subsequently beneficial outcome, and in case of control, the positive outcome is based on information and feedback. Feedback answers the question "Did my action work as I intended? Is the result beneficial for me?". The mutual inclusion of trust in control, and control in trust, show that trust and control cannot be completely separated but also, that control cannot be theoretically reduced to a special kind of trust, and trust cannot be reduced to a special kind of control. This means that actions to control situations can include many possibilities and assumptions and many things can go wrong, due to external events which are “out of control of the person”. Therefore, it is impossible to know every possible aspect, so complete control is impossible. On the other side of the extreme, trust also includes some kind of control, since actions are always based on information and beliefs about workings of an environment. If the smallest kind of feedback is received, and even if its the realization that no feedback came, trustors perceive it as confirmation or challenge of their inner model of the workings of the environment. This leads to assessment of the current situation and further actions and it is a control mechanism. So, even if people do have a lot of trust, they cannot be free of control mechanisms. Also, control includes trust in workings of a environment and trust also includes psychological bonding of feeling responsible. Therefore people choose their actions out of a combination of trust and

control and also stand on the receiving end of a combination of trust and control from other trustors. Trust and control are experienced per action, and the sum of those actions describe a range-like overall trust, or a range-like overall control. It is often simplified in trust of a person, as in "I have trust in person XY" or control as in "I have control over my device". This is a simplification based on a weighted sum of actions the person is trusted with, or the computer can be influenced by. If, in the overall picture, most of the past trust experiences were followed by beneficial outcome, then people say they trust someone. Also, if most of the inner workings of a device can be influenced, and past actions of control over this device were rewarded beneficially, the device is under control. Overall trust and control are therefore better thought of as ranges than as boolean values. The expression to trust or control a device is used accordingly in this section.

In the dress scenario we see trust being placed in devices. Sally and Theresa do not know, how their devices actually work, they do not know how the manipulation of those devices work, and which effect they will have on their lives. They take them into their most private areas of life, and become vulnerable. Sally puts trust in certain technological characteristics. She trusts that her data sharing settings are respected, she trusts that the feedback data she sees on her device is correct, and she trusts, that her data is not used against her. So she becomes vulnerable of being exploited over the gathered data, and she becomes vulnerable to the impact of devices on her daily life, e.g., by motivation of devices to do certain actions which do not benefit her. She is justified in her trusting, because she has no choice, but there is also no control mechanism which could work as evidence for trustworthiness.

Another kind of vulnerability is an integral component of quantified self devices. This vulnerability is being motivated or manipulated to certain actions. The functioning of this was described in more detail in the previous chapter, e.g., how human behavior can be influenced over feedback, over the mirror and chilling effects, and over certain aspects of self-images. Motivation and influence are vulnerabilities because of two things. Firstly, it is unknown whether goals of behind the motivation benefit users, in the long run, and secondly, every action includes risks. The risks may differ in scale and possible harm, but some are always there. These risks can come from usage that was not intended and eventually harm users, for example, Theresa's over overuse of the device. Additionally, if goals do not to benefit single users but instead serve other goals, e.g., societal, or other "higher" goals, they need to be justified against additional burden on users. For example, if devices would include the goal to make users consume more products, or to fulfill certain societal goals, then this needs to justify against the benefit of single

users. We see that there is necessity to protect the vulnerabilities users reveal by using quantified self devices. They need to be protected against manipulation and neglect of responsibility due to the distance between developers and end users. When users lack control over devices and therefore have no choice but trust without evidence for trustworthiness.

So the users lack of control over the devices leads to a need for trust, and the trust can be granted in a justified way, when those, who have control, i.e. developers truly acknowledge their responsibilities and thereby fulfill the crucial requirement (II) for trust relationships. As current market economy works with the overall goal to increase profit, a functioning trust relationship between users and developers is highly unlikely. The benefits of trust relationship can only be achieved if companies do not value their profits higher than the users welfare because otherwise they would constantly betray the users trust. They would need to truly try to fulfill the trust put into them by users. The benefit of the solution to protect vulnerabilities over a functioning trust relationship is that it would actually benefit users. Users gain indirect control over the device because their needs are taken seriously and the device would be changed so that it fits to users. Other kinds of justification, e.g., some of the excuses described in Section 5.3.2, do not work out beneficial for the user because they do not actually influence (or control) the situation. To achieve trust relationships, feedback lines to the developers are essential because otherwise developers cannot acknowledge any responsibility, because they would not even know about them. Ways to achieve this feedback are including users into development cycles as described later in the value sensitive design approach (Section 6.8) and also to include qualitative feedback which comes over service hotlines and similar feedback mechanisms.

When we observe the situation from the aspect of distribution of control mechanisms we need to ask whether this distribution is beneficial for the users happiness. This questions includes two parts. An analysis about the distribution of trust and control and whether it works out for users happiness. We see that functioning trust relationships are not established automatically, and this is aggravated by the fact that companies do not accept the users welfare as their responsibility, and prefer pure increase of profit ranges, instead. To increase trust into products from the market, other mechanisms exist. For example by legal regulation, as the EU general data protection regulation. Laws can be perceived as another, more indirect way of control, as long as people trust the institutions which assert the laws. These regulations can increase the trust in products because they shape the users assumption about the working of the products by creating evidence that the

products work in an expected, beneficial way. Therefore, regulations can lay foundation for trustworthiness. An example can be found in medication regulations. If the admission procedure for medication would not be that strict, it would be dangerous to take medicine, and taking medicine would be more difficult to justify. The same thing applies to regulation as the EU general data protection regulation. Revealing data to a web page would be less justifiable, if it is unknown what happens to the dataset. In comparison between trust relationship and controlling regulations, we need to acknowledge that the users' benefit of quantified self devices depend on a large range of circumstances, from personal predisposition to social embedding to technological implementation details. If trust relationships cannot be established, then many situations need to be regulated, i.e. controlled, in other ways to protect vulnerabilities of users. Trust relationship can evolve dynamically to users needs and if they would exist, users feedback would directly impact developers and devices. If the same level of protection by regulation has to be achieved by regulation, next to feedback from users to legislation, the whole regulation process is added as extra effort. Also, it would create extrinsic motivation for companies, which would lead to the expectation that companies only implement the minimum, because their real goals are differently. Instead, responsibility and trust relationship are two things which work from intrinsic motivation and from the human desire of relationship and social belonging. So increasing the acknowledged human responsibility on the side of companies would be an elegant way for devices to increase the benefit for users.

Next to functioning trust relationships and legal regulation, an opportunity people have to control the situation is trying to control the device themselves. Control over devices is constrained by opportunities of the users. Control opportunities are defined by settings, offered by devices, and also human by factors as the time, knowledge, wish of users to program their own devices. The pushing of certain goals and only letting users control the device in a limited way, for example whether they want to achieve 8k or 10k steps a day, does not leave enough room for experiences, observation and individual judgment. So the device is still in control, as long as it is used. In contrast to the lacking opportunities to control devices, devices offer feelings of control for the user over the users own life. Numerical feedback about their state of being, promises people knowledge, optimization opportunities, and control over their own lives. But to get the control, they have to trust the devices that their feedback is correct and that their implicit ways of usage will help them to fulfill their personal goals. Users need to give up control to gain control over the same thing. So this control users gain is an illusion of control. The counterquestion is not fulfilled. At the beginning of this chapter we saw, that true control is an action that

causes an outcome with a high possibility, and not doing this action causes the outcome to not happen. If users do not leave control to quantified self devices, they still have control over their fitness or whatever is tracked. They have even more control because they are not required to take the feedback from the device as truthful or to act according to their nudges. The question is, whether this kind of perception of control make users happy. It would, as long as people believe they themselves achieve a goal they chose. But some real benefits can only be achieved outside of the illusion. Benefits from changing overall goals, for example, require control outside of it. If users successfully transferred their believe of self-control and self-esteem from working with the device towards other things, they could successfully achieve a sense of control. At the same time, if people believe they can only be successful with extrinsic control, they learned something which impairs self-confidence. What users believe in the long run depends on individual users and their lives.

Another control mechanism, which users like Sally have, is the judgment of the device's feedback to her own experience. Sally can check for plausibility of their current sensory perception towards the situation. Here she runs in the problem, that some measured things cannot be perceived sensorially. For example, electrodermal activity cannot be felt. What can be felt is the current level of stress, which is not the same thing, but in the scenario her dress feedbacks her the stress level on basis of electrodermal activity, so it is comparable over the resulting information. If it mismatches regularly, she could learn that trust in the device is not justified in this context. In this case, the usage of the device for this purpose would become pointless. As we saw in the previous chapter, feedback from devices is likely to be trusted, even if it contradicts personal experience because otherwise the usage of the device would be futile. The belief, that the device feedbacks truths, deprives users of control and of free judgment of the situation. If judgment as control mechanism does not work sufficiently well, then people depend with a part of their wellbeing on the feedback of the device. If the device fits, it can benefit users for certain aspects and will not notice the dependency. If it does not fit users will likely receive negative feedback and feel bad about it or live in a state of discrepancy. In case of distribution of control, the control over the users 'truth' is placed on the side of the devices and is not helping users happiness when users have not enough doubt about the feedback to balance the scale. Since doubt is intrinsically challenged by pure usage, and also, from a technological side, quantified self devices never fit "good enough", it can be foreseen that this intrinsic lack of control of the user will impair the user's happiness.

The next part of this chapters questions whether trusting devices increases the happiness

of individuals. We follow the question, to what extend trust in devices adds at least one additional way for climbing up the hierarchy of needs, without impairing important other ways. A functioning trust relationship can increase peoples happiness, because it fulfills social needs. It also can fulfill esteem needs as it offers the opportunity for individuals to be heard and being accepted with their vulnerabilities. Trust relationships could improve some of the problematic effects of quantified self devices. For example, trust relationships could improve the believe that data is not abused for other reasons that eventually could harm the users. And even if the feeling of being monitored always includes some kind of mirror or chilling effect, being watched by a trusted entity might feel better and reduce pressure. We saw that trust relationships are hard to achieve in the human-device-developer setting. Instead of trust relationships, people reveal private vulnerabilities without controlling the social situation or the device and are therefore left with little options but trusting. This kind of trust, does not include the positive notion of being cared for, what people expect from trust. Instead it includes a notion of dependence. Dependence is an unpleasant state because it impairs autonomy, which is one of the basic values to climb up the hierarchy of needs. On the other hand, trust in devices removes a lot of responsibility for personal success. Users do not need to think about their own way to happiness but are guided to it. Support is not always wrong. In many situations support helps people achieve their goals. Not all ideas need to be discovered for themselves, and people learn from experience of others. These experiences are often told by their social environment but only work if people reflect about them and create their own version. Devices instead, are created to motivate certain actions, and do not leave room for own experience. The social equivalent to a quantified self device would be a controlling partner who checks in for daily fitness, for money spending habits, or for anything else, which the device monitors. If people would not accept this behavior from close relationships or every other person, and intuitively know that this behavior harms them, then there is no reason to accept the same behavior from devices. We compare it to love relationships because of the privacy level of information and the constant monitoring. This huge amount of intimate information is commonly only seen in very close and private relationships. As good partners support each other, a different design approaches but control could support users. If the device helps reflecting and experiencing, if it offers tips but can pull itself back, if it lets users breath in their own rhythm, then it can help climbing up their hierarchy of needs.

Trusting devices and their devices, especially over the own perception, can also impair happiness. Two reasons for it are discussed here. The first reason is the created distance

between perception and body by numbers. Optimizing life via numerical feedback can make small achievements feel good, and larger goals get out of focus. This is so, because optimization motivates to do actions, that are made important because of the anticipated positive numerical feedback, and not because of inner feelings of happiness. This means, that short lived small achievements are encouraged, while larger achievements can be discouraged. Satisfaction by small achievements impairs the ability of users to make themselves happy, because they need to listen to their bodies, to notice that in reality, they want to do something else than fulfilling the quantified self goals. This brings us to the second reason for impairment of happiness, the ignorance of socially discouraged activities. The inner guide is often questioned by devices and every little deviation from the devices goals are reflected as failures. It is easy to forget that the inner guide of people also includes things which people might call failure, but are actually positive things. For example lazyness, unproductiveness, agitation, spontaneity, are things which are implicitly discouraged and judged as something bad by quantified self devices. These things are not useless in peoples lives. They can help climbing up the hierarchy of needs. Hanging on the couch and and doing nothing helps to physical recover, and therefore helps with physical wellbeing an the basic level of the pyramid. Laziness and unproductivity also help with creativity and therefore can help with esteem and social needs. Agitation and anger are warning signs that something is going wrong and helps people with energy to change their situation. These things mean to be human and accepting them helps with esteem needs. The not-accepting attitude of devices, and the implicit assumption that people are failing with their fitness or calmness level, lead to the wish to control users. Also, if people wish to control themselves, they think they are failing, too, in certain topics. They do not trust themselves, so they aim to control themselves by being controlled. Learning to trust themselves is not going to be learned by letting oneself being controlled, but by experimenting with live. Here, happiness is impaired by trusting implicit world views how people should act an being constantly judged about them.

The next part will discuss the impact of quantified self on trust in interpersonal relationships and on self-confidence of users. Quantified self devices can impact the trust of interpersonal relationship over its communication and data sharing capabilities. In the dress scenario, the sharing of results is part of the whole smart clothing concept. This happens at Sally's work, in form of comparisons between companies by the accumulated achievements of all workers, and between participants in the yoga course. As described with the mirror and chilling effects (compare Section 5.3.5), and the self-regulation the-

ory (compare Section 5.3.2), people shy away from transgressing social norms in fear of consequences. This can be seen, for example, when Sally is annoyed about her co-worker getting pizza for lunch at work. She herself is doing a lot for the social goals, in contrast to the co-worker. So, she shows a little contempt towards him as a kind of sanction. Through the quantified self environment, vulnerabilities are increased, since co-workers receive additional opportunities impact goals and socially created self-esteem of one another. This influence is not based on naturally created trust, which would result from experiments with vulnerabilities, but is pushed by the goal of accumulated health points. To create the same level of motivation in a trusting way, the trust would need to be achieved in small steps and bidirectionally. This trust would include that co-workers achieve their part, and require that co-workers do not sanction them too brutally, when they slip up. To the contrary, since trust in the workplace dress scenario is unlikely to be created that way, vulnerabilities of disclosing information about fitness level (i.e. by eating pizza every day) can easily become targets of control mechanisms, where co-workers sanction each other for not accomplishing the task. As described before, people need to fulfill their own needs, to make themselves happy. The interpersonal control mechanism add an additional layer of pressure on users which has the same effect as the control by the devices. So individual goals, which are out of the norm, are sanctioned and the acceptance of the individuality of people is ignored. On the other hand, societal goals are rewarded. This leads to the basic discussion whether the luck of the society (or the many) is more important than the luck individual. This is an old controversial debate, which is out of the scope for this thesis. For this work, we do not think it is. It may be in life threatening or extreme situations, but in daily life, the wellbeing of private individuals has highest priority. Increasing the trust would need to accept individual differences and to support it over devices and environment. For example, not the accumulated number of steps is counting as success for Sally's workplace, but the achievement of individual goals.

The last part concerns trust and control users form towards themselves. As we saw, feedback of quantified self devices can influence and harm the trust people have for themselves (compare Section 5.3.1). Similar, as personal goals are created from external goals (compare Section 5.1.1), the self-image is created from the public image [63] and basis for self-esteem. In the worst case, people believe they do not have any talents, or that their actions do not have any impact on the world because their reflection is showing this. This would be total loss of trust in themselves, while with increasing trust, they believe they are able to achieve things. If people loose trust in something, they might feel

the incentive to control it instead. Users, who receive unsuccessful feedback, may it be from correctly technologically processed data or otherwise, loose trust that they achieve this goal on their own. This is, because devices reflect them failure, which they would not have noticed otherwise, and therefore the "uncertainty" involved in trusting themselves, becomes a reflection and certainty of failure. Another consequence after loosing trust in their actions, is the users' believe that they need feedback to control themselves, to eventually achieve their goal, and to become "certain". If the results still don't improve enough, they risk to feel even more in need to control. This is because if users improve their results, they do it without learning to trust themselves, because they are compelled to check the result of every action. They are impaired to develop trust in themselves (a.k.a. self-confidence) and trust in their own bodies, because uncertainty and physical sensations are treated as something that needs to be obliterated or at least corrected.

Self-confidence is based on trust in oneself independent from the view of others. Quantified self devices teach the exact opposite. They promise that people will feel good, strong, and self-confident as soon as they start to control (resp. "optimize") themselves by using the devices. Supporting self-confidence and trust in oneself depends on the goals and support of choices, including the free choice of discarding the device and its feedback. This would be true control users have over the situation and the device, independently from the control the devices graciously gifts them with. This control determines how far users can develop trust in themselves by permitting themselves uncertainty and experiments, and objecting feedback they receive from devices.

Examples can also be found in the dress scenario. If Theresa would not get negative feedback about her yoga performance, she could learn to listen to her body, an beginning with more easy exercises, which would fit better to her body. She could learn that she could do these things. Instead, the feedback she gets reflects failure and she includes this in her self-image. Since people always create their self-image from public image to some degree, the feedback itself causes her to repeatedly doubt herself. She sees that her results are worse than others, she compares herself to it. These mechanisms are built into human functioning. Therefore, it would be unfair to demand that people should have sufficient self-confidence to stand above all of it. Devices should be built to support human, emotional growth and not attacking it on several levels and then excuse it with further demands towards the ones who where hurt by it.

The loosing of self-confidence does not need to occur in every person. But it suggests of being more dangerous for some people than for others. Sallys self-confidence is thriving

within the realm of control, as far the system allows it, and she receives rewards for her actions. This rewards are positive feedback from the dress and a good place in the social comparison in the yoga course. Nevertheless, she can only can learn self-trust in the possibilities the device permits uncertainty, does not surveil her, and allows options for own decisions. Despite this, when she calms herself down in the self-management room at work, the important factor is not how she feels, but how her dress shows brighter colors. She trusts the device in this matter. The emphasis in this situation is not to independently achieve a good work life balance (which would also include saying no to external demands), or to feel and recognize that something is stressing her out and she needs to do something (also includes saying no). Instead, she meditates to optimize herself for the dress and the overall goal to be a well functioning citizen, employee, and person. There is a difference between the goal of self-optimization and self-awareness and well functioning live. The need or pressure for optimization is not based on trust in oneself, but in the believe of being a source of many failures and that they need to be trained away. This is contrary to self-trust and self-confidence and works over self-control. It adopts to the outer public image as the own, and rejects uncertainty, and vulnerability of trusting oneself. So, Sally, too, is not learning a broader sense of self-trust, but also functioning within a control system, and therefore only trusting and controlling oneself within the frame the control system leaves open. Self-confidence is important for peoples happiness because it influences how people see their own opportunities. As long as quantified self devices only support control mechanisms, they cannot help support the goal of happiness.

This chapter revealed doubt that quantified devices, as their are designed, contemporary and in the dress scenario, benefit users. Instead, true, accepting, and respectful trust relationships between users and developers would be an elegant way to create devices people would benefit from. In the current device-user relationship a lot of control lies only with the device. Devices influence, and therefore have control over, the "truth of the user" for self-judgement, and implicitly about the goals users. Since users lack control about them, they are prone to trust the devices without the evidence which would ideally precede a trust relationship. The lack of control leads to dependency which can only be partly positive if somebody wishes to give up control. Instead, devices discourage control and responsibility over the users life, while at the same time, claiming to offer those. The reason is found in the constant monitoring. Further the interpersonal trust can be impaired if users results are compared against each others, and self-confidence can be impaired because users do not learn to experience the world themselves but give

control to technical devices. To create devices which can be trusted, trust relationships would need to be created and maintained, which offer people control over devices. These devices would probably need to work completely different, because they would need to give up control over users and instead support them in their own goals. Trust and control are the basis in the formation of consent, integrity and deceit, which will be discussed in the next section.

6.3 Contextual Integrity, Informed Consent, and Deceit

In this section we examine the interplay between expectation of users and actions of devices. For this we summarize the concepts of informed consent, contextual integrity and deceit. We examine which expectations are transmitted with the usage of quantified self devices, to what extend they can be fulfilled and how they can be exploited. We look into the consequences of fulfilled and disappointed expectations and which consequences they have for users wellbeing. The following section is based on the information about informed consent and deceit from [31] and about contextual integrity from [56, Chapter 5].

Expectations are the basis of trust and control as described in chapter 6.2 in so far as they represent the model of the world on which is acted in a trusting or controlling way. These expectations can be changed by information offered. If an action A executed by agent B impacts agent C, B can asks for C's consent to that action. *Contextual integrity* means that C consents under all the information she has available, which includes expectations, which are not necessarily spoken out. In an "uninformed" state these expectations can include social conventions, psychological biases, and wrong information. The additional information offered to retrieve *informed consent*, has the task to paint a true picture of proceeding, outcomes, risks, and effects, so that the consent is given in an informed state. Informed consent aims to protect of safety, autonomy, trust, self-ownership, and personal integrity of individuals. It helps to avoid abuse and domination of one another. Furthermore, informed consent can only be given in an informed, voluntary and decisional-capacitated state. Giving consent is an act of trust and the presented information avoids abuses of this trust. For this, the offered information need to be complete and understandable. If critical information is left out or manipulation, e.g., threats or unfair comparison, is used to convince someone, the realm of *deceit* is entered. For different actions in different environments different forms of consent are required. In economy

another consent policy is used than for example for medical procedures. There is no abstract way of calculating the need of informed consent and the way in which it need to be retrieved. In this section, we will examine which kind of informed consent policy might be appropriate for quantified self devices which impacts the mind and the body of users. For this we look which expectations users have about the devices, what they should know, and comparing it to today's informed consent strategies for comparable products.

Quantified self devices in our story are treated as every day technological and economic items, despite that they can have substantial impact on the physical and mental wellbeing of users. With the promise of improving health and wellbeing they are marketed and the advertised benefits show that they are supposed to have impact on users. Otherwise they would be useless. In medical settings, several aspects define the necessity and the way how to obtain consent. These are the intensity of impact, the risks, how controversial and value-ridden a topic is, the privateness of the concerning object (e.g., body or data), the presence of conflict of interests, rate of supervision of the executing institution or practitioners, and the trust in the relationship. We examine quantified self devices under these aspects of informed consent in the medical field because these devices are created to influence bodies and minds of users. The impact on body and mind requires those devices to be handled more carefully than other technological objects, since bodies and minds can neither be escaped nor replaced. In contrast, other technological objects, for example smart locks, do not impact the physical body directly. Homes and possessions can be replaced. There is always a grey area because also burglary impacts the wellbeing of people and can, in extreme cases, result in physical assault. But the smart lock itself does not execute any harming action. So the development of those requires different ethical rules. Yet, quantified self devices are created to directly impact users bodies and minds and therefore need to be hold to other, more medical, standards than typical consumer technology.

The intensity of impact affects the requirements of informed consent. In bioethics, requirements for informed consent can be thought of having set of actions, where extensive informed consent is mandatory, non-negotiable, and supported by broad consensus. For example, in case of surgery. At the edge of this set of actions many things needs discussion about the form and necessity of informed consent. For example, sometimes consent can be presumed, e.g., in case of an traffic accident, when the injured person is unconscious and surgery is necessary for survival. But the same cases entail exceptions, for example if the injured persons denied blood transfusions beforehand. Some freely

marketed items that impact bodies can be compared to quantified self devices in their ethical requirements. In Germany exist restrictions and information obligations about freely sold medications and dietary products. Medications are, for example, always sold with solid information about possible side effects. Dietary products are forbidden to make wrong promises, e.g., time promises, how fast users can reduce their weight. Furthermore, consumers are advised that they need to eat healthy, additionally. For food products with some kind of artificial sweeteners, a warning about laxative side effects need to be placed upon the packaging. The packaging of cigarettes show warnings signs about side effects. In case of mental health, a warning about addictive risks of gambling is placed upon its advertisement. Although, laws do not determine whether something is ethically correct or not, they can give hints where people are concerned about justice. It is common knowledge that gambling can be addictive. In the case of quantified self devices a debate started in how far they elicit eating disorders and similar addictions.

Until now, Simpson and Mazzeo [55] showed that usage of fitness trackers is associated with eating disorder symptoms. Interestingly, not the calorie tracking was associated but the monitoring itself revealed the crucial association. Furthermore, the neglect of rest days and limits fitness trackers encourages overexercising and behavior that risks of the users. Also users showed withdrawal symptoms if they could not use them. Another concern apply to the binding of self-worth to numbers. Finally, Simpson and Mazzeo [55] showed concern about the ubiquity of quantified self technology that could trigger eating disorder symptoms and animates companies to encourage the usage of their trackers in accordance to professional recommendation so that triggering of eating disorders or fueling them can be avoided.

One aspect for the requirement of informed consent is whether the impact is so benign, that it is not needed. Eating disorders are a serious medical condition, so this does not count. Users of quantified self devices should be informed about this association, at least as user are are informed at the same level that addiction can be part of gambling. Simpson and Mazzeo [55] propose to use it in recommendation of professionals to minimize the risk is just one way of gaining informed consent. In this case, the information would come from a medical professional who is bound to bioethical standards and would inform the user. Other possibilities are similar warnings for devices as on gambling advertisement as "usage of fitness trackers can be addictive", information leaflets within the packaging about health risks, and recommendations to use them in agreement with medical professionals. Also producers, computer scientists, and user experience designers can take part in making devices less potentially harmful. Limitations for physical activities can be im-

plemented, as well as rest days can be encouraged. From the technological side, devices would just stop counting those extra exercises. Health could be the main goal in the user stories of quantified self devices, instead of appearance. In [55] was said that most users use fitness tracker to improve their appearance and not their health. To improve health with exercise people do not need to be thin or muscular. Being thin or muscular as the goal behind most user stories because those devices are marketed freely and these goals are easy to sell. They take the same niche as diet food. Diet food is not allowed to promise weight loss in specific time frames. Quantified self applications promise that by creating weight loss plans. Some applications let users enter their current weight and their goal weight. Then users decide how fast they want to achieve that, in the "hard" way, which means the smallest time frame of X weeks, an "easy" way in a longer time frame, and a middle option. Then it shows how many calories need to be saved for each day. The calculation if these plans does not include rest or cheat days if they are not implemented, it does not show any error ranges either. It just implicitly promises, "if you follow this plan, track all your exercise and restrict your calorie intake as shown, you will be thin or muscular in Y weeks". Reasons we see for prohibiting advertisement with promises of successful weight reduction in case of dietary products is that the promise is either wrong to begin with, or only applies under optimal conditions. If people get overwhelmed with hunger and overeat, or if their bodies do not loose weight easily for physical reasons, e.g., hypothyroidism, or they just have a different natural weight, they won't succeed. The world of users is too complex for these kind of simple solutions. The same reasoning should apply to quantified self devices. One difference between the restriction of advertisment for dietary products and quantified self devices, is that advertisment works before the purchase and restrictions to quantified self applications work when the device is already bought. So the wrong promises of advertising would lead to monetary costs without the (promised) success of the slimmer body and additional health risks. In contrast false promises from software of quantified self devices would lead a lot of misspend cognitive energy, time, exercise and in the worst case, even physical harm,. This happens under the same promise that they users become thinner or more muscular. The promised time frame act as a kind of deceit because it is unlikely to work out this way because of the simplified world view. For dietary products they are forbidden, but for having them implicitly implemented in the design of software, they are not restricted in any way. Software is allowed to create food and exercise plans that increase exercise for individuals, which would naturally increase the need for food, but at the same time encourages a crucial cut of calories. There is no check on these numbers, no safety warnings, no explanation how these numbers are created, users have nobody to ask if they

have problems following through with the plan or any other problem. All of these things would be considered unethical and a violation of the information requirement of informed consent, if any nutritionist or medical professional would do this while developing exercise and food plans for patients. From professionals, patients would expect to consider their personal circumstances, they would expect to be informed comprehensively with as many details as necessary and to be open for questions later, and they would need the professionals to be independent of further commercial interest, or at least inform openly about it. It makes no sense that algorithms, which are much more likely to be wrong than humans (compare the context discussion in Section 4.2.3), should be hold up to less strict ethical standards than humans. To the contrary, the conflictedness of participating parties, companies in case of quantified self devices, asks for a stricter level of informed consent procedures [31] than a trust relationship between professional physicians or nutritionists with their patients. One might argue, everybody knows that these algorithms and their results cannot be trusted, and need to be handled carefully. We object this because this view would end in an ongoing battle whom to believe, the own body or the results from the device. Since the usage of a device only makes sense if the device is believed at least partially, the usage alone implies that things are believed which might be failure prone. So this argument might change the focus which computed information is believed, but it does not solve the problem. One sensible way to clarify the situation would be for users of quantified self devices to acquire additional information they can trust. Which is exactly what would also be needed for informed consent.

Consent itself has the ability to render actions ethically allowed, which under normal other circumstances are not allowed. Nevertheless, the mere presence of a underwritten consent form is not enough as long as the voluntariness is not ensured. Consent needs to be given freely [31]. This includes the free choice to choose things which are not necessarily beneficial for them. Voluntary consent can be invalidated by literal coercion, undue inducement and no-choice situation. In the following, we will go through these reasons, and compare whether some of them happen in our dress scenario or in product design of quantified self devices. Coercion is the threat that non-consent will leave individuals worse of then consenting to an proposed action. This includes not only direct threats as “if you don’t do this, i will harm you”, but also implicit threats, like the prospect of being denied future actions, treatments or other benefits. Furthermore, threats do not necessarily need to be said out loud. In hierarchical relationships the pessimistic belief of individuals that something bad will happen if they don’t consent can be enough to consider given consent involuntarily. In our dress scenario we can see

this in the financial motivation to use the dress. There is an financial threat of loosing the bonuses from the insurance. So the usage itself cannot be considered voluntarily, at least, if people lack financial wealth. The same is true for using quantified self technology at work, as Sally and her co-workers do. The hierarchical relationship between employer and employee itself reduces the voluntariness in the decision of usage. Employees may ask themselves whether they be even be continued to be employed if they deny the usage, especially if the majority of co-workers comply with the usage. They run the risk of making themselves disliked by the employer and co-workers. Undue inducements refer to promises and creation of temptation which make it hard for people to make rational choices. For example, airline tickets in exchange for a kidney, would be such a case. We don't see this within the dress example. No-choice situations refer to the lack of decent alternatives so that an unsafe choice needs to be taken. In the dress scenario we do not have this explicitly written out. Nevertheless, if quantified self devices and the attached software is required to be used, and although several kinds of appliances exist, users cannot find any, which is for example, not judgmental in their user experience. Judgments in user experience design might be the representation of results as "good" or "bad", or can even come from comparison to past results ("today your exercising was 28 % less extensive than yesterday"). Together with the pressure to choose one device, users would have no choice to choose an appliance which is beneficial for them, they would be in a no choice situation. Then, the consent for usage of one particular device cannot be considered voluntarily, anymore.

Deceit is the action of using trust and given consent of a person for the own beneficial outcome and risking the beneficial outcome of the trustor resp. consenting individual. This can happen, if the contextual integrity of consenting partners is not considered and insufficient information is exchanged. The deceiving action does not need to be acted out knowingly, it suffices that, with appropriate effort, the trustee could have known it better. On the technological side, trust can be deceived in different ways. An often mentioned kind of betrayal is the misuse of gathered data (comp. Section 5.1). Information can be misused to analyze it without permission, to share it with third parties, and to use it as reason for denying options in the future, for example bank loans or medical procedures. This kind of information misuse is already constrained in many countries, for example by the General Data Protection Regulation of the EU. Other kinds of deceit are also possible. For example, if users consent to usage under the expectation that the information and feedback of devices is interpreted sufficiently correct, then wrongly interpreted data can risk their physical wellbeing. User interaction design of

devices or their infrastructural embedding have, on the one hand, the opportunity to support people who have intrinsically the same goals as the user stories. Fitness tracker, for example, can actually help to reduce weight but are also associated with disordered eating habits [55]. But if, on the other hand, devices start or risk of worsening their health, for example by intensification or elicitation of eating disorder symptoms, users are deceived. On a side note, in the field user experience it is commonly known that users tend to blame themselves for not handling the devices correctly. This does not free producers to neglect their information and consent obligation they have and therefore pushing all responsibility towards the user.

This section showed how contextual integrity links to informed consent over the users understanding of all relevant information. We saw that the object of risk is the users body and from this rises the need for an extensive risk assessment and information. Quantified self devices are no toys because they influence the highly private and irreplaceable human body. From this emerges the requirement for informing users, comparably to information patients would receive from a professional in this situation, for example pharmacists, physicians, nutritionists, or psychologists. If this cannot be provided, they need to encourage users to get additional support. If the risk of eliciting and strengthening eating disorder behaviors is shown to be similar to the risk of gambling for addiction, at least similar requirements would arise. Warnings like "tracking oneself can lead to addiction" would help with this. Probably, the need for informing users about the addiction risk might be even more severe, because at least, gambling cannot directly cause death. Another action to improve the situation is to market quantified self devices as what they are, medical instruments, instead of an enticing way to adapt the own body to unrealistic beauty and fitness standards. On the technological side, the judgment of user interface could be reduced as an effort to reduce risk to elicit or strengthen addictive symptoms in users.

6.4 Paternalism

Paternalism describes the human undertaking of acting or deciding for another person in a well-meant manner. Thereby, it limits the freedom of the other person. Paternalism is defined in [30] as:

> X acts paternalistically towards Y by doing (omitting) Z:

1. Z (or its omission) interferes with the liberty or autonomy of Y.
2. X does so without the consent of Y.
3. X does so only because X believes Z will improve the welfare of Y (where this includes preventing his welfare from diminishing), or in some way promote the interests, values, or good of Y.

Paternalistic actions can originate in diverse X's as institutions, governments, or individual persons. The justification or rejection of paternalism depend on the situation and its perceived norm. For example parents are supposed to act in favor of their child and challenging this kind of paternalism needs justification. In contrast, paternalism towards reasonable adults always needs to be justified. For example, favoring long term goals over short term temptation can provide such a rational for paternalism, as can be seen in the requirement of using seat belts in cars.

The question in this chapter is to what extend technological products as the dress can become paternalistic, which effects the paternalism has on users and which actions are appropriate to minimize risks.

In the dress story, some situations turn out to be paternalistic. The coffee machines denies caffeinated beverages for Sally because she is already stressed. Health insurance companies base their actions on the believe that everybody needs physical exercise, and users are supposed to ensure the realization. Questionable is, whether feedback from the dress itself can be paternalistic. For example, Sally's device itself interprets her data to warn about increasing temperature. She did not ask for it. The question here is, whether this action interferes with Sally's autonomy. Individuals should decide for themselves to leave some things unknown. The argument is that knowledge can be a burden, especially if it urges to certain actions. If Sally can change that the way and content of notifications, e.g., less analysis of her physical state, the feedback action would be less paternalistic because her autonomy would be retained. Nevertheless, the pre-defined default action can be seen as paternalistic and opens up discussions about nudges.

Nudges are actions that do not force decisions or actions on people, but use psychological tendencies to influence decisions [30]. For example, a default value is more often retained by users than changed. Nudges over default values work because it takes individuals energy to change the status quo. This can be used to nudge users into certain decisions. For example, if Sally would have been asked openly whether she wants to be alerted of her improved temperature, she might have decided differently. Visualizing results, e.g., step

count or stress level, can also be considered nudging, when the representation suggest a certain behavior. For example, the dress looses its colorful brightness subject to the stress level of the wearer. This nudge motivates users to calm themselves down. Additionally, the vibration nudge on her arm aims for the same goal. So, next to the paternalism from the environment, the dress itself also acts paternalistic by nudging people into certain behavior.

One general problem of nudging and paternalism is the transference of an image of unreasonable adults. It pretends that Sally cannot decide on her own, whether she wants to uphold the stress level, whether she wants to push herself with caffeine, and whether she pursuits physical exercise.

As described in Section 5.3.1, the reflection of a person which is transfered externally is eventually included into the self-image of individuals, if it is not fully rejected, e.g., by excuses as in Section 5.3.2. If users accept the image of an incompetent self which cannot fulfill their own fitness and health goals without self-tracking, they can become dependent on devices for it. On the other hand, nudging can be quite effective if people want to use it to optimize themselves. Nevertheless, devices could support a much more healthy self-image of the user by helping them to maintain their autonomy and liberty. Paternalism sounds like a quick solution to fix problems but since its deprives autonomy the question is what users gain in exchange. The long term goal is to increase the overall health, so the effects on health are analyzed to be sufficient to justify the prevalence of paternalism. The Guardian [5] reports that the impact from fitness trackers alone on the user is not effective enough to improve the physical activity of users. The best working incentive to improve physical exercise was cash, followed by donations for charity and at last rewards only given by devices. But even by paying money as reward the exercise of users decreased over one year until it stabilized at the level previous to the trial. Hence, we highly doubt that ubiquitous use of quantified self devices would lead to an improvement of health or sustained behavior change. If this happens, the cash incentive in the dress scenario would be just a tax for living a human live as it unfolds for the individuals. In certain cases though, fitness trackers can help. When people are intrinsically motivated to change, the information from trackers can be helpful resource [16]. Research [40] states that even in the cases where intrinsic motivation is expected, e.g., weight loss programs, standard interventions on weight loss are effective but the fitness tracker does not add benefits for the users. [1]

[1] On a side note, it seems highly questionable whether weight loss and health can be equated. Nevertheless, it is the typical baseline of many articles of the quantified self discussion. The connection

From all indication, fitness tracker appear to be a comfortable tool for intrinsically motivated people to check on their exercise routine. In [16] fitness trackers amplified feelings of autonomy and self-efficacy for intrinsically motivated users. Thereby, many of those users expressed the wish for more support from implemented "coaches" in the application. Also, users welcomed the additional feedback about their sleep cycles and stated to understand themselves better. They welcomed the influence on their behavior by the devices and felt improvement over exercising without any device or coaching software. Also, no questioning about the reliability evaluated data from the device was reported. Further, effectiveness of the fitness tracker were not set in comparison to users who exercise without one. Nevertheless, users reported that they wished for more options for personalization of goals. Here we see the constrains on autonomy by the predefined user stories. Users like to pursuit their own goals instead of accepting the pre-defined ones. The wish for more personalization and more support from computerized coaches can be interpreted as such a wish. The problem here is that people do not wish the achievement of their own goal (fitness) but a concrete way to it by using better coaches. So if coaches are implemented in any way by using sub-goals, the autonomy would also be constrained. Even if several choices are given, there would be only more pre-defined ways. Hence, quantified self devices do constrain autonomy and override decisions of users through their inability to adjust to the users needs (comp. Section 5.2). To reduce paternalism, information and suggestions could be given without pre-defining any goals. In this case, the autonomy would be less constrained.
One could argue, that the autonomy is not as much constrained, since users are free to exercise without the devices. But if feelings of self-efficacy and autonomy improve with the help of the devices, there is also the risk and the fear of users, that without using the devices, these feelings cannot be maintained. So there is motivation to act within the range of action supported by the device. Therefore, users are motivated to act according to the paternalism.

The definition of paternalism requires transgression of consent. In [16], the users are intrinsically motivated and want to use the devices. Nevertheless, the question is how informed they are about the inner workings of these devices. The lack of questioning the feedback of the devices contradicts against deeper technological criticism, as well as it is just not common to know the inner workings of technological devices. Furthermore, the users of [16] wished for more context integration of their live events. As it may seem beneficial for self-evaluation, there is no questioning how this information is tracked

between body weight and health is an interesting discussion which leads too far for this thesis.

and how it is used in algorithms later on. So there are two possibilities. Either, the users are gave consent not fully informed about the devices, or they have given consent not caring for those things. In the former case, the feedback of coaching software, and the un-adaptiveness of goals can be considered mild paternalism because the informed consent condition for paternalism is satisfied. It is mild, because todays fitness trackers and application are not mandatory in usage. Nevertheless, if they are used, users expose themselves to technological paternalism at least in form of nudging.

It seems as if fitness tracker may be mostly effective as a tool for people who already exercise regularly. They can visualize their achievements and push themselves towards certain fitness goals under different level of personalization options. This kind of paternalism is justified, if the users are informed about the risks and the accuracy of data and its evaluation process. The additional information would render the usage less or non-paternalistic because the paternalism definition assumes the transgression of consent.

In the dress story, the approach to force or nudge with devices and the external interpretation of the users reality is clearly paternalistic. The justification base on a wrong conclusion. People who use the devices voluntarily are fit because they are intrinsically motivated for exercise beforehand and acquired the fitness tracker to support their own goal. They do not get fit because they use them. So pushing the usage of quantified as extrinsic motivation may be a waste of time. Furthermore, the consent is questionable as long as the risks are not known by users. The risks include without limitation discrimination of certain user groups (as described in detail in Section 6.7), and the risk of addiction for vulnerable users (as described in Section 6.1 and 6.3). We do not see that paternalism is justified for the gain in case of extrinsic motivation, e.g., pushed or imposed motivation. For intrinsic motivated users of contemporary fitness trackers the paternalism is acceptable as long as they are informed about the risks.

6.5 Responsibility

The development of technology has the ability to impact the world and the future of individuals. In this section focuses on the definition of responsibility and how responsibility is distributed in the example of the of the intelligent dress and its usage. We see how responsible development can be achieved effectively and which effects neglected responsibility in case of quantified self can have.

The discussion about the responsibility in technology has tradition. One well-known dilemma is the development of weapons because the harm which can be caused by them. With weapons, the causality with harm is obvious, so in many cases, the development of weapons is treated with reluctance by designers and engineers. In other cases, the causal coherence between development of technology and their outcome in the world is less obvious. Many things influence how technology is used, and which effect it has on users and environment. For example, in the dress scenario, people do not get addiction solely from the presence of any exercise monitoring system. They probably also have other problems. Maybe they were in a critical phase of their live, pr they never learned to handle problems in any better way. If people learn to believe they cannot manage their exercise or daily life without support from devices, maybe the users were trained to follow paternalism in many other ways before, e.g., by other devices or the society they live in. During the development cycle of technology, many things are unknown, and user stories can evolve quite different in reality because of other external influences.

The uncertainty in a complex world lays the foundation between obligation and responsibility. Responsibility is defined as conscious actions which are based on reasoning and include a subjective dedication which exceeds pure obligation [36][2]. Obligation is a well defined range of actions to execute in certain situation. For this, the situations need to be known before defining the duties. This gets increasingly harder in an increasingly complex world, where not all situations and influences can be known. Also, the wish for rules in every situation removes autonomy and freedom from the world and is therefore unrewarding. Responsibility dissolves the conflict between duty and personal freedom. It leaves room for personalization of certain task under the umbrella of a joint societal goal. Additionally, responsibility distinguished itself from duty by requiring a form of ethical engagement of the individual or institution which takes on the responsibility. The value of duty and responsibility lies in the cohesion of society. Humans alone are not able to survive on their own. So, humans adopt roles which fulfill those duties and responsibilities, so that society at a whole can survive. When the world changes somehow, for example by technological advancement, roles, duties, and responsibilities can be redistributed. The dress scenario shows an unequal distribution of power and responsibility. The societal goal is to have healthy individuals. At the same time, the environment does not provide that, otherwise there would be no need to nudge people into certain behavior. The nudging of the individuals with the help of quantified self systems to balance out stress and unhealthy living conditions, is pushing responsibility for this deficiency on individu-

[2]This whole section is based on information and definitions from [36].

als. Other possibilities would be to have a less stressful and physical limiting (working) environment. Responsible approaches from the workplace would for example, limiting the daily office hours or other methods to reduce workplace stress. Other approaches to a less stressing environment could be the support the usage of public transport services, providing parking space for bicycles and ergonomic workstations, and start a workplace running team, without the pressure to take part and support it financially. Here we see the unequal distribution of power. Since employers depend on their workplace for a living, they need to put up with the environment which is provided. Providing a healthy environment seems more complex than pushing responsibility to employees because several influences from several actors need to be balanced. The simplicity of the solution is increased, when the responsibility is pushed towards the last actor in the chain, the individual. Mämecke [46] states how the originally emancipatory endeavor of taking health in their own hands by using quantified self technology is slowly changed towards paternalistic surveillance and demands, simply because the choice of usage is given to institutions while the compensation is left to the user. But responsibility for their health this cannot be "pushed" to individuals because "pushing" would be duty and, as defined, "subjective dedication" goes beyond that. Instead of accepting responsibility subjectively, the shift of demands towards individuals, as in the story, is based on dependency and distribution of power. Companies and other institutions receive the benefits. They try to achieve their goal cheaply. They do not want to think about the environment they are creating. They do not need to provide healthy workplaces, when employees are forced to balance the health consequences out on their own. Institutions, which hold the most influence and power over a situation are the ones who need to take responsibility. The reason is, they have the biggest impact and can make the most positive changes. If the market and employment market cannot provide that, than lawmakers should consider taking on the responsibility, because they are the ones with enough influence to change the situation.

Another question is, whether the devices themselves "behave" responsible towards users. Inanimate objects themselves cannot take on responsibility, because they do not have free will. Nevertheless, their handling is designed and therefore it results in responsible user experience design. We saw, users are influenced over the feedback they receive from devices. Since people trust quantified self devices with their personal health, designers and developers should accept responsibility over the effects they have. Designers have the power to influence the users self-image, they can nudge them into healthy or unhealthy behavior, and they can, in the worst case, trigger or reinforce addiction. So the power lies at the companies, which develop quantified self devices and, in the worst case,

the users pay the price with their health. Similar to the environment example above, users are required to balance out the risk from the device when the power lays with the producer. The power over the devices can also be used responsible by informing over the shortcomings of devices, instead of demanding compliance users. Also, producers of quantified self devices can look into the effect of their devices before bringing it to the market. This is also part of responsible acting. In most university research including human participants, strict ethical rules need to be applied before testing things on humans. In the case of consumer technology, the same device has often less strict rules. In Germany, electronic devices need to get a safety check so that the product is physically safe, e.g., it will not explode, but the software or user experience is not part of any such review. Reviews of software and design is often met with criticism because regular updates change the software, so software certification would theoretically be needed with every update. This would be expensive and lead to slower update circles. On the other hand, for some form of software, regulations over usability already exists. In the EU, public institutions are obliged to alter their websites accessible for users with vision-impairments, hear-impairments and physical disabilities [14]. Here, the responsibility is accepted by lawmakers and placed as a duty upon website operators with the help of guidelines[3] to diminish structural discrimination of people with disabilities. So it is possible to require standards about usability and place responsibility on the ones who have the power for change. If producers do not accept the responsibility of "nice" software on themselves, similar procedures as the BITV could be used for the design of quantified self devices and their testing before launching. Next to non-judgmental user experience design, accepting responsibility would mean to learn as much as possible about future usage and risks device. It would mean to observe the domestication cycle, not only to improve selling points, but also how devices can be misused or causing harm. Afterwards, responsible development cycles would try to minimize the risks and inform users about the risks which cannot be excluded, so that informed consent is ensured. For example, misconceptions arising from inaccuracies, failures, skews during the knowledge creation, and the biased assumptions that technological captures exercise results were neutral, need to be corrected. Guidelines and legislation may be only one solution for responsible reaction towards risk of quantified self design. The main point from the definition of responsibility is, that some agent with the power to change something needs accept ethical commitment to change the situation and to not let the market and coincidences define the outcome. The most vulnerable individuals should not be forced to compensate the health risk of quantified self devices. This would be irresponsible by definition.

[3] They can be found under "Barrierefreie-Informationstechnik-Verordnung - BITV 2.0" [2]

In summary, we saw that responsibility of welfare from usage of quantified self devices should be accepted by producers and lawmakers. It would irresponsible to let it work out by the market itself because this would eventually put the power to the companies and institutions and let the users pay the price with their health.

6.6 Privacy

Privacy is defined as a non public space where individual are free from social, or other external influences, or at least, act within trusted places. This gives space to critical reflection of current events and experiences. Individuals and society benefit from privacy, because ist allows mistakes, experiments, and critical reflection. All of these are necessary to develop individual personality, and also to reflect on external expectations, motivations and general structures of society. Thereby, it is not enough to distinguish between private and public [19]. Not everything what happens in a public space is public. Instead, privacy is a social context, and the interpretation of the involved individuals matter.

The discussion about privacy is recently known for the General Data Protection Regulation of the EU and for discussions about data retention by states and law enforcement agencies. Supporters of data retention argue that it is necessary for prevention and prosecution of serious crimes as terrorism, child pornography, and many others [13]. The other side argues that people have the right for informational self-determination, that putting them under general suspicion is unacceptable, and that data retention has only small to none success in prosecution. Every party seems to agree that trade-off between privacy and the common goal of safety is a difficult one. It is therefore justified only for the most serious crimes because the interference with the individuals privacy is severe. On the other side, people enjoy the usage of ubiquitous technology, which also invades privacy. This is often used as an argument for data retention because if people offer it to companies voluntarily, then the need for privacy seems to be less important. The gain from commercial technology is often less severe than physical safety, provided by data retention, so the state should have the ability to save its citizens with similar technology. But there are several differences here. People have control over their device, which they do not feel to have over agencies spying on their communication. And further, the advantage for usage is much more concrete. Social media, quantified self devices and similar data intensive applications offer social connection, self-definition, or feelings of control. This might be one reason why there is greater acceptance of commercial technology might

than for state interference. This does not make a statement about the moral justification about the reduction of privacy. The argument that people reveal their data in case of privately used technology, too, and are therefore supposed to allow it from state agencies is a paternalistic and faulty one. Paternalistic, because it prescribes opinion people should have, and faulty, because nobody needs to give permission to something only because she gave permission to something else. In its substance the General Data Protection Regulation of the EU restricts exploitative privacy invasion of personal data and therefore shows that privacy has value on its own in the society. The only restrictions of privacy seem to come from serious safety reasons and informed consent. The societal benefit through the lack of privacy in the dress scenario is not covered by either of this argumentations. Terrorism or child pornography are much more serious crimes then self inflected health problems of responsible adults. Also, healthy living can be promoted in different ways than in constant monitoring of users, so there is not even a need for that. Still, consenting adults are free to accept the reduction of their privacy as described in Section 6.3.

In the rest of this section we examine the effects of monitoring systems, as intelligent dresses, on privacy. We check which parts of privacy it would influence and which effects can be triggered on the development as an individual and for the society. Information about privacy and its workings in this section bases on [23]. In this section we focus on the societal and psychological benefits of privacy and search for structural proposals which would safeguard privacy. We recognize the on-going discussions about information privacy, which demands individuals to decide on their own about the usage of their data, but we do not focus on that. We are more interested in structural changes on a larger scale, in contrast to pushing responsibility for the usage of data on individuals. Doubtless, individuals should be able to decide about the usage of their data. Yet, privacy is more than sharing and evaluation of data sets.

The importance of breathing room for individuals provided by privacy is essential for all personal development but also the basis for societal development on a larger scale. When humans are alone, and do not feel monitored (and judged by extension) by other humans or machines, they can freely try out things and thoughts which they do not express in societal context. They have the personal space to acknowledge how they feel about something without the fear that somebody notices and judges. Privacy also increases creativity, because of the lack of judgment. Through experimenting, creative planning and reflection, people define who they are, acknowledge what they feel, experience what they can do, and decide which external values and opinions are adopted, changed and

rejected. When this space of privacy is reduced, these opportunities for self-definition are also reduced. Then, people can prevalently experience themselves through the lens of the external environment, since they cannot create the distance for critical reflection. In the dress scenario, Sally's stress and exercise is evaluated at every moment. Because of this surveillance, her chance to try and experiencing the activity of "doing nothing" is reduced, because she is always nudged to fulfill the dresses goals. The personal, private space of her body is therefore intruded by the device. She experiences the continuous external judgment of the device. Her ability to experience her own body is reduced. Theresa experiences this in a more critical way. She already longs for another kind of body experience because she does not feel good and reacts with minimal effort in the imposed yoga course. Her self experience and definition is continuously undermined by the device in a more severe way. It works against her own intuition, transmitting the image that her intuition is wrong, which is a way to transferring the image that people themselves are somehow wrong. How constantly doubting personal experience can harm people can be seen in the manipulation form of gaslighting [8]. Gaslighting is a harmful form of manipulation which is not meant to equated with the situation of the dress scenario. Nevertheless, there are some comparable structures in the process. During gaslighting, individuals are made believe that their own perception of the environment is wrong. The goal of the manipulator is to isolate the victim, for example by saying their friends do not really like them, and then gain control by making victims believe, that the only one who can be trusted is the manipulator. Finally, victims adopt the views of the manipulator and try to change themselves to fit to the view of the manipulator. The similarity of the process of gaslighting and the dress scenario comes from external prescription of ones reality, e.g., the device states somebody did not fulfill the daily step goal for fitness (so they can't be fit), even when users already feel tired from exercise. Gaslighting itself can lead to serious psychological consequences for the victim, for example depression, anxiety, panic attacks and more severe ones like dissociation or psychosis. In its essence, manipulative gaslighting involves more, e.g., isolation of the victim. Nevertheless, it shows that reserving the interpretation of reality to the environment or devices might be a risky idea. If it goes wrong, people get in the situation where they, comparable to gaslighting, cannot balance out the discrepancy between their point of view (which would include their needs) and the reality reflected on them. The lack of privacy would hamper the reflection about the situation further, so that opposing experiences cannot be made. Theresa has already changed her life away from the complete surveillance of the quantified self environment. She only participates in the yoga course. But this participation cannot be called voluntarily and is therefore an transgression of her private

space in form of bodily autonomy. The transferred image is that she does not know what is good for herself, and that that physical exercise need to be imposed on her. This is a kind of distortion of reality which is also what gaslighting does to victims.

Devices and their embedding in the society shape the perception of reality of users also in other ways. They reward options, which users chose, with benefits and also determine which option are available. So people who constantly use monitoring systems are prone to learn their environment by looking through the lens of the devices. Decisions and the resulting experiences physically shape the brain. After a while situation are judged based through the option they got offered. The less privacy for own creative experiencing is left, the more people judge by the pre-given option because there is no space to learn other things. Also the perception of individuals would change. People search for known patterns, and if they are constantly monitored and learned to optimize themselves, they search for these external-reflection-to-self-optimize pattern. The experience of oneself would then also work through this pattern. Also the usage of monitoring systems and their feedback is an consuming activity, not creative one. Open ended, creative self-development is replaced by consumption of external feedback, nudging and reward systems, and in the end, self-impression management. Thereby, creativity is necessary for conquering unknown situations in general. Without creativity it seems questionable how people can learn to live independently, and with increasing spread of monitoring systems, there is a risk that people become increasingly dependent individuals, if no countermovement is formed. To reduce this risk, monitoring systems should be left out of private and intimate spaces. They may be useful for some therapeutic interventions, but the promise of self-optimization is most often an optimization to external goals. It creates dependency and can hamper autonomy because of the lack of privacy. The promise not to share information, as current technology does, does not help because it would not change the situation that humans generally do not feel private and safe if they are monitored. We doubt that the monitoring effect of behaving differently and the lack of creativity will be restored, just by the knowledge, that the data is not shared. This would always depend on the trust individual users grant the devices. Questions for consent and informing of data collecting policies can only go so far as trying its best, but it cannot replace the security and safety of private places. Another, less rigorous, approach to extend the breathing room, is to make the devices less addictive, so that users can easily avoid them. Traditionally, technology producers try to increase the time they can bind the user to their product. This is the basic attitude which leads to the transgression of privacy boundaries.

If we take a look at whole societies, we see different patterns. In a society, institutions create opportunities for citizens, and not the devices alone. The optimization goal is to render adjusting their own proceedings so that they work most effective with the citizens. This proceeding is independent of whether it works through technological devices or any other institution. But with usage of devices, institutions get the opportunities to check whether their approaches work. They do not need to do to manually create a theory, then collect data to check it, and afterwards implement changes. They can increase the speed by having done the experimenting and evaluation by self-learning algorithms. This works by placing small changes and incentives through devices, then evaluating the results directly, and changing processes directly. Thereby, a loop of mutual influence is created between users and algorithm. With algorithms, these evaluation and changes can be fast, and therein, the algorithms optimize profits for companies or other values which were set as goals. One of the problems is, that if a majority of people are susceptible to rewards, the algorithm will focus on rewards to optimize their goals. At the same time other motivations, for example curiosity or altruism, are expected to be neglected. Such a society would be trained to work for rewards, which are often some kind of consumption. Things which can be achieved by curiosity or altruism, e.g., inventions or social stuff, are prone to be pushed further in the background. This kind of motivation does not get the same rewards while learning new things, so it becomes more difficult to pursue. This also influences democratic decision making. Many political decisions have some basis in altruism, e.g., social security. If people learn to always judge through the lens of reward, they will tend to choose options which work by rewards, and not with e.g., altruism. So lack of privacy can lead to focus on a reward system, which would then change the society to neglect altruistic goals. A societal countermovement would be needed for balance. Also, if the reward system leads to less creativity of individuals, a society would suffer from less inventions and slowed progress.

The dress scenario does not contain a description of its society, but the behavior of the protagonist can be analyzed. For example, the importance to gain benefits by quantified self devices is quite high for the individual. Sally is often thinking about her devices, her steps, her stress level, and her yoga course. It is important for her. She also notices that the bus ride is sometimes wrongly interpreted as physical exercise, so her mind circles around these topics. It can overwrite leisure, where creative thoughts would be possible. Jogging in place while toothbrushing hampers the probability to have a interesting creative thought in the same time. Also, if everything depends on rewards, she would ask herself, if she does something altruistic, what will she get for it? Where is

the (external) reward? It would feel strange to do things for other motivations. Also the employers importance to support those exercises would probably be affected by increased focus on rewards. At least, if the participation of employers in the exercise competition is rewarded for the company. The precise characteristics of increased focus on rewards cannot be foreseen, because many influences would figure into that. But the society would increasingly manifest its reward system not only in one, but in many ways, because this is what people live every day on small scale.

Also, the algorithms tend to optimize towards specific goals. This goal is not the individual healths, because this is too specific. Big Data algorithms don't concentrate on the specifics, they optimize for a majority. This effect is seen with Theresa. The environment in form of institutions learned, that the exercise (steps or yoga course) is best for all, by minimal costs. Not much private room is left for her self-development.

There are several ways to counteract this trend. As descried before, data exchange needs boundaries. This would hamper the feedback cycle for the algorithmic optimization. These kind of boundaries can be implemented, by only allowing data to be used within the context of the observation. Next to the boundaries, the rewards system can be adjusted. There could be rewards for living independently without surveillance. There could be rewards for thoughts that may rise discomfort and for creativity in solution findings as well as in self-expression. Some kind of discomfort is always included in being confronted with new ideas. This discomfort leads to reflection and opinion formation. For example, algorithms should not personalize results, as many search engines and social networks do, self-expression (and opinions) should not be harshly judged and silenced, and trying other things next to the prescribed ones, should be supported and not (indirectly) punished. Next to the reward system, altruism, curiosity and other motivations need their place in society, too. These places should be left open and free of any monitoring or reward system. This can be supported by purposely safeguarding private spaces for intimacy, human interaction, research, reading, journalism, creativity, exercise, religion, and probably many other activities. They should exist safe from influence of any monitoring technology. And they should also not be (indirectly) punished to use, for example by not getting bonuses somewhere else.

In this section we examined the role of privacy for individuals and for societies in regard to monitoring technology, as quantified self environments. It was argued that monitoring technology hampers the ability of individuals for self-development and that even large scale democratic processes base on the self-development of individuals. So, the impact

of optimization of the individual can risk to transform society to be increasingly reward oriented, uncreative, and decreasingly solidary. We saw that the surveillance itself is the reason for change, and therefore, boundaries of data usage and informed consent is not enough to maintain those values. Private spaces need to be safeguarded and supported for the ability of individuals to develop their own personality and opinions, and to preserve democratic decision making.

6.7 Justice and Fairness

Discussions about justice in social systems have a long tradition and over time several theories developed what justice in societies means. This section analyses, whether a society as depicted in the dress story is fair, can be fair, and whether simple changes would make them more or less fair. Furthermore, we deduce that quantified self devices strengthen prior existing norms, and can lead to discrimination of minorities, who do not fit these norms. We discuss the argument to establishing more freedom of individuals by opening up software and hardware designs and conclude these as unrealistic in case of mainstream devices. Justice in this section does not mean the fair behavior of individuals but the fairness of complete societies [38].

Rawls developed a theory of justice [38], which we use to analyze the society in the dress scenario. We use this theory, because it is widely accepted and used, e.g., in [56, Chapter 5.6.3], and occurs reasonable. He states, fair systems see fair treatment of its members as a basic human right. Basic goods need to be distributed equitably. This fair distribution is not only requested for material goods, but also for rights, freedom, opportunities, power, income, wealth, and self-respect. Rawls' basic idea bases on the model of social contracts: Imagine a society without any rules, and people need to adjust their coexistence by contracts. These contract would establish basic rights, in a way that nobody is underprivileged, e.g., "I don't kill you, if you don't kill me". People negotiate these contracts under a "veil of ignorance". This means, they negotiate under uncertainty which role in the society they would personally play and which privileges they would have. We use the word "privilege" as the societal advantages people receive because of societal valued statuses, e.g., because of their membership in social classes, gender, race, religion, level of education, and others. Respectively, "underprivileged" means the lack thereof. Under the veil of ignorance the negotiators would not know whether they would be poor, rich, highly intelligent, which gender they would have, or any other

privilege. Thus, they cannot gamble for the "best personal, egoistic result", and the wisest choice would be a minimax strategy. Minimax strategy ensures the best outcome for the worst case in an unknown environment. So everybody would see themselves in the shoes of the most underprivileged individuals in society because themselves could end in this position, and therefore would negotiate the best possible outcome for those individuals. Another main point of Rawls' theory of justice is the argumentation against utilitarianism. Utilitarianism is an ethical idea that the optimal fair society is created when the greatest number of people receive the greatest benefits. The problem with this concept is that the collective goal of a society is more valued than of the rights one individual human being. From utilitarian perspective it would be fair that one person dies so that e.g., 100 people survive. Rawls' theory states that the collective goal is not of more worth of individuals. His principle of putting oneself in the shoes of the weakest member of society and optimize their lives first, declines that idea.

The most underprivileged member of our story is Theresa. Her well-being depends on opportunities and control executed by the smart clothes and their societal embedding. She suffers from health problems, so she has problems acting according to the systems demands and therefore cannot gain benefits from it. Rawls states that most underprivileged individuals should have the biggest benefits of an unequal distribution of goods. According to this theory, Theresa should be supported to come out of her miserable situation. But the yoga course does not help her, instead, it increases the problem. Also the counting of steps had hurt her. Additionally, by sharing her bad results communally in the yoga course, and by being threatened with higher health insurance costs, the problem increases further. She has no opportunity to do something good for herself to get out of this reinforcing loop. This makes the system unfair for people with unrecognized or undiscovered health problems. We assume that nobody wants to be in Theresa's place, which is the first clue, that the depicted system might not be fair.

The domestication process of users by devices determines which opportunities users receive. The reason is, that users can only act within the opportunities quantified self devices and quantified self environments offer. Distribution of opportunities is one of the characteristics which determine the fairness of a society. Devices themselves can impact the fairness of a system by acting as executioners to deploy certain values of society and ignore other ones. These values are determined by the pre-thought user stories during the devices design process, or by conclusions from clustering and classification algorithms, which also use an existing society as its base. If devices implement stricter rules as necessary by society, they may worsen the freedom, which in itself, does not necessarily mean

they would worsen the fairness. If the value itself enhances freedom and opportunities for the most underprivileged individuals, the fairness would increase. If devices implement values which only fit already privileged individuals, they may worsen fairness. For example, if during the development of a quantified self devices only had been thought about male costumers, women would probably receive worse results, because their bodies are different. If the user stories during the design consider that women may have different results, and treat those as equal by design, the fairness between men and women would increase. The value of *equality* would have been included during the design process and the fairness, by treating different people differently according to their needs, would have been respected. If devices or technical innovation give more opportunities to users, even power distribution can shift. An example for the broadening of opportunities is the invention of the internet itself. It functioned as a platform and enabled before unknown usages. For example, individual users became famous, a lot of money was and is made through it, people have the opportunity to reach a large audience and sometimes staying anonymous while doing it. So, opportunities can increase fairness, but in many other cases new opportunities include similar prejudices and unfairness as the society behind it. We see the reason for the broadening of opportunities by providing platforms for self-development of individuals. Therefore, if fairness should be increased or maintained, the value of individual *freedom* is important in user stories.

Quantified self devices are usually created with user stories emphasizing self-optimization and self-control. They do not aim to provide a platform for self-development, but implement an idea *how* personal development of the user should look like. For this reason, users have only few possibilities to change the way of usage and therefore little freedom and little control over the opportunities offered to them. On the one hand, in conversion phase of domestication process, users are able to use devices in new, unexpected ways. On the other hand, the design and behavior itself is not influenced by individuals. Even if there are opportunities to personalize a device, those opportunities are also based on preceding user stories. Of course, personalization can have varying degrees of freedom, but the meta level of changing the device itself, cannot be accomplished this way. Devices can be implemented in an open source kind of way to increase adjustment opportunities of devices. Hardware and software can be made accessible, and software can be made rewritable for users purposes. This gives a larger degree of freedom to adjust the usage of devices. But only a small group of people, those with time and knowledge to do all this, are able to adjust those devices. The others stay users on the receiving side of the table. They stay dependent on producers firmware or downloadable open source options. In the

latter, user stories, are not created by them, but the society, but this does not change the dependence on someone else's ideas. Furthermore, the proposition to let people program their own devices to increase justice is unrealistic. Companies use a number of N people to develop those devices, and now one individual should be responsible to develop their own software for N devices. This is not working just from the time users have available. So we see, that opportunities made by devices cannot support every individual users goals and ways of usage, but only a subset usages defined by society and companies. The opportunities are therefore always restricted by pre-thought user stories. This means, that (in)justice of society is included in devices and they are therefore maximal as fair as the society which created them. Conversion phase of domestication process cannot compensate this because every way of usage during conversion still depends on the design of the device with its user stories of self-optimization and self-control. In the end, the "weakest" user can only have one meta choice to use a device and its opportunities, or to not use the device. Therefore, societal (in)justice is executed on them by quantified self devices.

The motivation to quantify oneself plays a key role for the justice of a system. Pressure and sanctions narrow down opportunities which can be chosen by individuals. Broadening of opportunities cannot be done through bare motivation of one individual. If the environment does not offer opportunities, individual motivation cannot compensate. Only further motivation to change the system which offers opportunities could achieve this. This applies to communal, pushed, imposed and exploited self-tracking. Also, the usage of quantified self devices in the dress example is not voluntarily. It is pushed by health insurance and by the workplace. Also communal motivation is active, e.g., by the fitness courses which motivates by social comparison. Furthermore, Theresa and Sally join their course as friends, which also keeps them motivated. Thereby, we saw that pressure does not need to be imposed directly. Especially social sanctions can be indirect. So, what would change if the motivation for usage quantified self devices would be only private and communal, but not triggered by agencies? Could this increase fairness?
Direct financial pressure would not exist to the same extend. Nevertheless, with large distribution of devices within the social groups of users, the usage of devices would become normal, usage and curves would become a part of life. The premise of "communal" motivation would include that results would be shared and compared because communal motivation works by comparison (compare Section 5.3.4 and Section 5.3.5). We expect, that curves can even become status symbols, because they represent the achievement within those communities. Not using those devices, would lead to social sanctions, as

being not part of the group. Still, social opportunities would be determined by results, and other kinds of opportunities would be received prevalently in comparison with the financial motivation of usage. Another kind of communal motivation is called the "the fear of missing out" [59]. This fear is based on the human desire to be part of groups, and is important for the self-esteem. It is defined as the fear to be excluded from social events which, for example, are distributed over social media. It leads to behavior as repeatedly checking of those websites. Individuals without satisfying real life social interactions are especially prone for this fear. Also the maintenance of a valued online persona (compare Section 5.3.5) is part of communal motivation. This means, not only societal opportunities are received as result of communal motivation, but also feelings of self-esteem and self-respect. Self-respect, a.k.a. self-esteem, is the feeling towards oneself in comparison to the value of others [42]. Individuals with high self-esteem feel as part of the group, and that they are doing the right thing. Individuals with low self-esteem tend to feel towards their own person as failure. Self-esteem monitors the self-value to ensure that individuals stay part of social groups. Failures and rejection lower self-esteem. According to Rawls' theory, the distribution of feelings of self-respect is part of a societies justice. From this perspective, we see that accumulated data by quantified self devices create a basis for self-respect. It represents social value and is typically raw and unadorned. Comparing this data to others threatens the feelings of personal value. This is comparable to sport competitions in school and the social comparison of the results, or selection procedures for team sport during physical education. Individuals who do not pursue sports or fitness in their free time do not get get elected on sport teams and get receive worse results and therefore can feel devalued. Also, in contrast to results in other subjects than physical education, the personal level of fitness is often obvious to everyone because it is equated with thinness and muscles and this cannot hardly be hidden. So communal motivation in quantified self environments would extend those feelings from physical eduction into adulthood and everyday life.

Another threat of feelings of personal value from devices on basis of communal motivation is that individuals are expected to spend their free time in a certain way [23]. Individuals with other interest than sports, would be pushed to pursue activities which do not give them a sense of self-respect. Additionally, many of them would receive worse results, than the ones, who are intrinsically interested in sports and competition. This leads to a further reduction of feeling of personal value for the former individuals, since they cannot spend their free time to act according to their own wishes and feelings of self-worth. This is discrimination by personal interest and is payed for by self-development choices.

Generally, pressure to act in certain ways, especially against personal wishes, attacks self-respect of people. Users of feedback devices take the risk of perceiving themselves as failing because the device and the assumption that feedback leads to improvement do not fit to their lives. Ironically, also people who do not feel challenged by a goal, e.g., because challenges are not challenging for them, can become unmotivated and fall back behind their peers. We saw that in one third of all cases, users stuck at their current levels of achievement or get worse (compare Section 5.3.4). Because of this, they have to cope with attacks on their self-esteem. So, we expect this one third of all users to be discriminated because the unequal distribution of self-respect (resp. self-esteem). It is programmed in the devices because they work on the basis of comparative feedback.

Other privileges influencing the success of fitness activities are based on health of physical and mental health, to even do sports. So communal motivation as described would also discriminate against people, who are ill or disabled, who need to work long hours and therefore have no time nor energy left to exercise, who do not have the money for healthy food, and who do not have the mental abilities to exercise regularly, for example individuals with depression or sleeping disorders.

A further problem with social motivation is, that societal standards distributed like this, are learned and internalized. After internalizing, it is hard for individual to even recognize them as socially pushed and not personal. Privileged individuals further learn, that their privilege (e.g., of being fit), is normal, expected, and for achievable for everybody. Because of this communal motivation can easily lead to dismissive explanation of the failure of others, especially, because people tend interpret sanctions to broken social norms as fair (compare Section 5.1.1 and [56, Chapter 5.6.3]). Hence, fairness perception (compare Section 5.3.2) can easily lead to to victim blaming ("why is he not just doing sports, I can achieve that, and I am not that fit"). In the end, consequences of societal standards, based on broad distribution of quantified self devices, even if it is "only" communally motivated, would not only result in unfair distribution of opportunities but also attack the self-worth of underprivileged individuals, and therefore is unfair according to Rawls theory.

To round up, the relation between fairness and the quantified self devices like the dress is, that it benefits unfairness and discrimination in society, and this is based on implicit user stories, next to conclusions of clustering and classification algorithms. Devices are made to work for a 'majority' of people (the 'majority' does not need to be a numeric majority, it means a large group of possible users), which automatically leads to discrimination

against those who are not part of this 'majority'. This discrimination is based on the unfair distribution of opportunities and self-worth. Furthermore, the greatest good for the greatest number of people is the principle of an ethical theory called utilitarianism, which is highly controversial. In Rawls' theory utilitarianism is considered unfair, because the collective good is of more worth as the individual, which contradicts a basic human right, that everybody has the same worth. So, quantified self devices as described, especially if their usage bases in pushed motivation, e.g., by institutions or communities, cannot be considered fair.

6.8 Value Sensitive Design

Value sensitive design ([56, Chapter 13], [54]) describes an approach develop technological products to function in accordance to ethical values. While some inexplicit requirements for software are followed in typical software development cycles, ethical values do not occur in this list. In software engineering those values built into software are efficiency, dependability, safety and security. Value sensitive design is a development method for products which aims to discover additional ethical values important for stakeholders and adds them to the requirements of the product. The idea behind value sensitive design is that if values are not implemented thoughtfully and intentionally, than subconscious assumptions and values are implemented into the products. So the idea is to consciously support values, which are important for future users. Software and product development processes work in incrementing circles of tasks. During the early stages of development, ethical values need to be included as goals. In the process, a holistic view on the product needs to be preserved and current decisions need to be constantly judged against the compliance to the ethical properties as well as the traditional software development values. In this section, two development cycles are described which interact with one another. The first one is the economical product development view, the other one is the technological, i.e. software development development circle. Thereafter, value sensitive design is presented as advancement to these, and the dress scenario is analyzed following the example of this design method.

A product development circle (compare Fig. 6.2) from the economical side of view traditionally consists of five stages. Between all of them are the gates, which are function as tests for the current project. They need to be passed to enter the next stage. After the initial idea of the product, the first gate checks whether the product fits to the company

Figure 6.2: Technological products pass several stages during development.

itself. The product need to be in the range of the financial and technical feasibility and risks. After that it enters the "scoping" phase, where ideas, risks and potentials are developed in a more concrete way. This phase is supposed to be relatively short. The goal is to see a realistic scale of the product idea. The second gate also checks for feasibility but much more strictly, because thereafter follow more expensive development stages. Once this gate is passed, a business case is planned around the product. This includes market and costumer research but also technical requirements and definitions to determine costs. After passing the third gate, the technological development starts. During development stage traditional (or other) software development circles take place. Constant feedback needs to be included and the holistic view on the product becomes critical, since small decisions in user experience design or algorithmic design can break the ethical requirements. The fourth stage can be entered when the development is finished and the product is in its first official version. This stage consist of testing and validation of the product. This includes also testing with potential users. If tests are not passed or errors occur in this stage, the prototype needs to be fixed. The testing can also result in a change of the business plan, or, if the product is not accepted by users, the whole process is stopped. If this stage is successfully finished, the fifth stage consist of marketing and launching the product. In general, companies try to make products fail as early as possible to reduce costs. Therefore the transgression between stages need critical assessment.

A typical software development cycle is part of the development stage, but overlaps with the stages 2 and 4 for requirements and testing. With agile development techniques the development incrementally improves rapidly implemented prototypes. Such an software development circle consist stages (compare Fig. 6.3), which firstly analyze the requirements and determine objectives of the product. Thereafter, risks are analyzed and alternatives are examined. Also, first prototyping can fall in this stage. After this, a stage of more intense development, testing, and verification is entered. Herein, ethi-

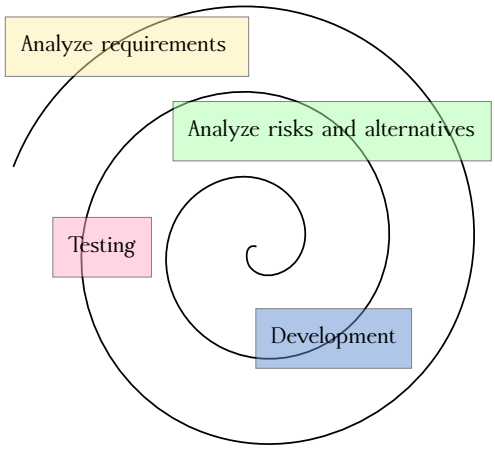


Figure 6.3: Software development typically iterates several times through the same tasks until the product is ready for the market.

cal problems can be discovered with the prototype. During this stage the holistic view on software needs to hold with extra effort. In agile software development models, i.e. Scrum, abstract values are prone fall behind more short lived tasks. While finishing user stories and tickets creates measurable and visible success from one week to another, even traditional meta values as architectural structure of the software are easily neglected. The reason is, that they require work as refactoring of software which cannot be seen from the users view. Nevertheless they cost money and time, and also, they cannot be tested automatically. Ethical values are even more abstract and feel far away from daily development routines. They are even more prone to fall behind, because in comparison with, e.g., software architecture, they do not benefit developers in the first place. They need to be aware in the developers mind while coding because compromises to finish a specific task can compromise the value. So, the testing stage requires a holistic view and thorough testing of ethical values. After testing and verification, the planning stage for the next phases is entered. Therein is evaluated, what needs to be done next. Since this model is incremental, again, the planning leads to definition of requirements, goals and constrains, and the circle starts again.

Ethical values need to be included from the first requirement assessment of products (stage 1 and stage 2). Subsequently added requirements can entail immense costs or render an already designed or developed product unusable. Value Sensitive Design is an design method to add to product development processes, also consist of stages: *value*

discovery, value conceptualization, *empirical value investigation*, and *technical value investigation*. Its first stage fits to the respective first stages of product development process and software development circle. The first stage of Value Sensitive Design calls for *value discovery*. Ethical values are discovered by identifying stakeholders and their concerns. Stakeholders are people, like users and second-degree users, or anybody who might be concerned or affected by the usage of the product. They are confronted with the ideas and raise their concerns and opinions. In the story, although it is fictional, Sally and Theres are stakeholders because they are users, but also employers, doctors, yoga instructors, relatives of first-degree users because they are affected. With fictional user stories, developers and product designers can also try to take look into effects, impact, and possible concerns of stakeholders, using their empathy. For the first step of identifying stakeholder, this might be practical but the opinion of real people is more interesting because it has the chance to open up topics product designers don't know about. When someone like Theresa would be included in the process of the development of the next fitness tracker, she, probably, could say something about their addictive risk. Also, she could raise concerns about ubiquitous imposition of physical exercise. Sally could say something about the paternalism of the coffee maker. Every stakeholder has their unique view, but for best results a representative range of stakeholders should be used. Thereafter, raised concerns and opinions need to be mapped to ethical values. In the case of the dress the affected values would be health, autonomy, free choices, self-expression, power, truth, knowledge and transparency, privacy, security, reputation, interpersonal relationships, and democratic processes. These values do not share the same level of abstractness but emerged out of the analysis in the previous chapters. They base on reflections of ethical, psychological, sociological and computer science literature.

Health: is influenced because the users body is effected by the usage. Theresa overdid her exercise and got harmed. Also, the device is supposed to improve overall fitness and health.

Autonomy, free choices: Many choices in the extend of usage, monitoring, and own decision making are not made by the user.

Self-expression: The users free time is occupied by devices, the dress decides which colors it shows, and the exercise is not freely chosen.

Power: With the shift of the spending of free time and the decision making towards institutions, the power about these things also shifts.

Success: Success and feelings of success are influenced over the comparison to an average or to a minimal goal.

Happiness is influenced because everybody should have the chance to feel good about themselves and their lives, even if they do not fit standards. Furthermore, more options to choose lead to more options for happiness.

Truth, Knowledge, and Transparency are influenced because data is recorded and evaluated to give feedback to the users. It needs to be truthfull and correct. Users also need to understand limitations and risks of the devices. Correct and comprising information is needed as a basis for free choices.

Privacy: Most intimate areas of live are touched and most intimate data is recorded and reflected. People need privacy for self-development and learning. Society needs privacy for innovation and responsible citizens.

Security: Most intimate data need to be safe. No other than the persons and institutions users consented to in an informed manner should ever get these informations.

Reputation: The reputation of companies and their employees depend on the activities of the employees. Also, the users image represented towards others is influenced by comparisons from devices. Furthermore, information about the users exercise is transmitted to the health insurance company. The individual price of the insurance depends on this reputation.

Interpersonal relationship: Friends, Co-workers, Employers, even love relationships can be effected by interpersonal comparison or by the price for the health insurance.

Democratic processes are influenced by the previously mentioned lack of privacy and in so far as the view on the world is changed, and that leading from external sources is implemented in the most intimate areas of the life.

The next step in value sensitive design is *value conceptualization*. During this stage, the evaluation of previously found value takes place. The analysis of values entails, what those values mean to the users, which parts this value consists of, and how the value maps to the design of the product. Also, values can interfere with one another, this is also checked during this stage. Lastly, it is analyzed what the law requires to fulfill a certain value, e.g., as it does with requirements for users with disability [2].

The value of *health* consist of two parts, physical and mental health. One of the reasons for usage of quantified self devices is physical health itself. Therefore, devices need support this. Actually impacting this goal in a helpful way and promising it, are two separate things. If the devices usage can turn into harming users, it stands in the way of that. This risk need need to be diminished. In case of mental health, risks of addictions need to be diminished. Also the growing of peoples autonomy (see below) improves mental health, thereby dependency can reduce it. So the users autonomy need to be preserved.

In the case of *autonomy, freedom and free choices* some concerns can be concluded from the story. The choices of spending the users own time is reduced. So, time and options are an issue. More precisely, the options of not using devices, the option of how to use them, how often to use them, and for which goal they are used. Also how much feedback is returned to them, how often and how intensely users are interrupted. Here also the nudging need to be considered. In general, how much of energy of their mind do users spend for the devices and its consequences on their lives.

Self-expression links to autonomy, in case of time and energy spend on the device and decisions over their lives. But also, the representation of oneself towards the society. The interpretation of the users fitness is also an act of self-expression because humans tend to optimize that. Not only for the health insurance and doctors, which may be trusted for their confidentiality. But also in case of work, or in case of the color the dress shows. Fitness and calmness can become increasingly interpreted by social circles. So social comparison is an issue for self expression. Also, the interpretation of being part of an group effort can be an act of self-expression. On the one hand, people do not want to be the one to hold back a group effort, but also tend to leave effort to a group because they feel not personally responsible, on the other hand.

Power is the ability to influence people, decisions, outcome or course of actions. The value of power is represented over devices because it enables people to modify their behavior and bodies. Also, institutions and companies influence areas of life over quantified self devices. This is done by implementing goals and implicit values in devices which strengthen power dynamics. Power dynamics are strengthened because users cannot change them easily in devices, and because implicit values assumptions and goals are so pushed to the users. If a certain kind of exception to the rules is not considered during design phase or by artificial intelligence algorithms, the individual who depends on the exception is marginalized. For example, if women are not part of the design

process, devices will probably not take in regard menstruation, or different body characteristics (as it is an ongoing discussion for example in the development of medication). So, the artificial intelligence and interpretation on the basis of majority, might increase profit for companies, might also increase average health, but on the cost of marginalized groups. Individual decisions, may they be from the individual or even for the individual, paternalism is another topic, is a starting point.

Feelings of *success* are part of the usage of quantified self devices. Success describes the achievement of goals. People can feel success not only for achieving a goal which was defined before the activity, but also they can feel success because they achieved a part of that goal. Also success can be ostensible. It can look like success, believed to be success, and turnout as failure. Also success can be only pretense. Feelings of success arise from achieving goals shown by devices. Success is always bound to a goal, and devices interpret those goals as numbers which must be met in one way or the other. Actions for goals which cannot be measured cannot be analyzed by computers. As long as this holds, feedback, including messages of success cannot truthfully transmitted for these kind of activities. Also, success can the be false. Even if users exceed all measured expectations of quantified self devices, they can still be ill. Success and health are linked implicitly in quantified self devices, which do not necessarily correspond. Also success and power have an interaction. Successful actions do not need to feel successful for the user, when the goal was not set by the individual.

Happiness can be achieved when basic needs are ensured and people can develop themselves in a direction they choose. Therefore it is linked to many other values. Health, safety, social connection and autonomy are some of them. Happiness is quite abstract and can be also outlined by the absence of sorrow. This does not have to be complete. But the overall outline of happiness needs to "feel right". Also, happiness is not momentary joy, and also not necessarily a chain of joyful moments, but the overall "climate" of happiness. So if other values are balanced out and preserved by design and usage of an device, then they do not stand in the way of users happiness.

Truth, Knowledge, and Transparency (compare Section 6.1 and 6.3) create part of the basis of autonomy and free choices. Without a clear view on the situation people cannot make informed choices for their path to happiness. Truth, Knowledge and Transparency are touched by tracking and evaluation technologies. There are two aspects on truth. On the one hand, truth always describes the coherence between a thing and a statement. Thereby statements do not need to be spoken, they can also be believed, even uncon-

sciously. When statement and thing coincide, we speak of truth of that statement. In computer science, truth from propositional calculus (also other logical systems are possible) is used in every piece of software. Since every step in programs are logic, software is sometimes believed to be neutral and that truth or knowledge can be created with that logic. This is not necessarily correct, because for once, programs would need to be a complete copy of the real world, but also, because the real world itself does not necessarily follow logical rules. So with every logically calculated step of the program, the differences to the real world increase, because aspects of the real world are not included. Knowledge is interpreted data which is hold by a person (compare Section 6.1). This means that the interpretation of feedback also plays a role. Without the interpretation of feedback by the users, quantified self devices would not have any effect. Transparency is of value because the interpretation by the user to create knowledge needs to be as correct as possible to enable informed choices. For this transparency serves for users assessment of risks, benefits, inner workings of the device, and how they use their device. Also are these values captured in laws as the general data protection regulation in the EU. It guarantees a certain amount of transparency for users. Such regulations must be met.

Privacy (compare Section 6.6) consist the usage of tracked data, by intrusion into private spaces by both monitoring and manipulating, and is also linked to self-development, since self-expression is constrained.

Security is a typical computer science issue, especially if personal data is collected. It includes technical components. On the other hand, if this kind of personal data is collected at all, there is always the risk of legal institutions asking for access to data and devices. The broader the interaction of the device with the environment, the more it can become also susceptible for intrusion. Also, providing security needs regular updates.

The value of *reputation* concerns the outer representation of a person or a social group. It is an immaterial good of a person or group and can be build on many values which people value themselves. For example, people feel better about others who share their own values. Nevertheless, reputation does not need to be in accordance to reality because it only concerns the appearance. If the difference between reputation and reality drift apart exceeds a certain limit, and it becomes publicly known, is can be perceived as a scandal in the public. Reputation is a value which is felt, not calculated by pro-con-lists. It affects power, trust, and social inclusion. For companies, reputation also affects

directly their financial wellbeing. People tend to buy products from companies they feel good about. Individuals with upstanding social reputation are often trusted and liked.

Interpersonal relationships are a value which people need to be happy. Relationships are part of every aspect of life. For certain situations people act in certain roles, e.g., sister, consumer, employee, or friend. People become happy when they can choose their roles or at least how to fulfill them. Every pressure to act opposing to those wishes results in unsatisfying relationships. In case of the dress, not only the relationship to other people are affected, but also more abstractly, in which roles the person is put by the devices, and whether this role, affect other roles. Ine example is the question, whether users can be (feel as, be perceived as) a good employees if their devices affects their reputation in a bad way.

Democratic processes are handled as societal values in the modern societies. As described in Chapter 6.6, a working privacy is basis for that, because personal reflection leads to free opinion formation. Democratic processes are furthermore based on values as *justice* and *tolerance*. If people do not value those goals privately, because of algorithms or environment teach otherwise, the ability to follow them in a whole society is harmed. Also, tolerance need to be intolerant against intolerant tendencies in society, since this would destroy the tolerance and therefore democracy itself. Further, tolerance need to be learned and is therefore good to establish as a value in every day objects.

The next stage in Value Sensitive Design is *empirical value investigation*. This is not a single stage, but is used at the same time as the other stages. The goal of empirical value investigation is to find values and concerns of stakeholders by directly considering their opinions. Including stakeholders helps to the cover context in the assessment of products. Only stakeholders know what is important in certain situation that they use a product. The qualitative questioning is done first, to discover the values. Later, these concerns can be analyzed quantitatively with the goal to weigh values against each other. For this, concerns can be translated into concrete design propositions of features. Then, testers are asked to rate them according to values. From a certain percentage of concerned users, the design need to be changed so that the feature respects the corresponding value. On the other hand, some features implement certain values. If a number of test users supports that idea, the feature should be included in the project. When features are sufficiently matured, test users can be asked for the importance of the feature. This is especially interesting if values contradict each other. A traditional conflict often emerges between comfort and data protection. By balancing values, some might turn out to be not that

important to the users. On the other hand, values which unfold their benefit on the long run, might be considered less important. So, the acceptance of users is not a proof that a product does not transgress certain values, because the users also learned certain values from which they judge (compare Chapter 6.6). Nevertheless, the information is important for producers, too, because a product which openly contradict users values and leave them with a feeling of unease, will also not be bought voluntarily. So empirical value investigation is helpful but not sufficient to assert that all important values are considered.

Empirical value investigation for the dress is hardly done, since it is fictional. Nevertheless, Asimakopoulos et al. [16] did an empirical investigation for fitness trackers. Ethical values were not evaluated but wishes and motivation users of fitness trackers. Test users valued feelings of autonomy and self-efficacy (which translates to success, self-development, happiness). The paper brings attention to the value of *leadership* since people want to learn from the application and wish improved guidance for their exercise routines. In a development cycle, this additional value would also need to be analyzed. The wish for leadership is based upon the wish to learn and to successfully achieve a goal. So, knowledge and success are part of it. Also, responsibility seems to be a part, since the users obviously prefer a teacher before learning for themselves. Another value might be *comfort*, because next to the possibility to ask for guidance, reading a book about the issue or inventing some method for themselves would also be given. Another wish from the users is more context integration and increased analysis of coherences. This links to the same values as the leadership issue. In a empirical value analysis these values would be needed to be balanced against each other. One question to ask such test users would be, whether their wishes and their positive assessment of quantified self devices persist under the knowledge of correctness of tracked data, the ramifications of big data algorithms, and knowledge how feelings of self-efficacy are created. Starting from this point, features for quantified self devices can be proposed in the next stage. For example, personalizing the color change of the dress, so that only users know whether they are stressed or that it can be turned of completely. This would, for example, enhance privacy. After the stage of empirical value investigation, development teams should be able to translate the emerged values into technical systems.

The proposal of personalizing color change of the dress, would be part of the next stage of Value Sensitive Design, *technical value investigation*. In this stage, technical features for products are designed on the basis of the results of the previous analyzing stages. Also the analysis of the new ideas belongs to that stage. An example for the dress scenario is

that intimate body data collection is a privacy threat. Maybe a new feature to increase privacy could be that the tracking only works when activated, and then is only executed for a specified time frame. Thereafter, tracking stops automatically. Personalization of color change of the dress, would also help with reputation and privacy issues. For truth, knowledge and transparency, information about the risk of usage and calculated error frames of sensors (as described in Section 6.3) would help. The power shift towards the producers is inherently given, from the development point of view. For the daily routine, the extra start button for tracking would also help. An option to gain autonomy would be to design the product with the goal to make people independent of them. Teaching users to meditate, but thereafter products should make themselves dispensable. Here it also depends how important the leadership value is for the user. Maybe a personalizable "assistance level" could help with that. The support of users autonomy and privacy would also help with the preserving of democratic processes. Success can be reached if goals are personalizable, but also partial success is praised. Also, goals can be supported in a non-numerical way. Instead of counting steps devices could be designed for asking how somebody is feeling physically, and giving options what to do, and maybe asking for reflection after an activity so that users decide for themselves what feels good. Being healthy feels good after all, so people could discover that for themselves this way. These kind of design features could be implemented and tested. In this way, an intelligent dress could be designed which is less morally questionable, than the one in the story.

Value sensitive design also requires additional knowledge within development teams. The first stage of value discovery needs empathy to find the correct stakeholders, and the second stage (value conceptualization) needs knowledge about values and their coherences and composition to find those new ideas. This is knowledge, that cannot be presumed in current software development teams. Only the position of user experience designers goes in the same direction, but is much more focused on handling everyday usability, and mostly aims for a pleasure short term experience with distinct values as beauty and seamless usage. In development teams, this knowledge needs to be learned, provided and practiced to implement the correct values directly into products. On the one hand this is costly for companies, on the other hand, people will like to use the resulting products. Also, we see contradicting values between the aim of binding users to generate profits for companies as done today. From this analysis it seems, that ethical products can be designed on a basic goal to create simple tools which help with one task and on the same time also support users in their autonomy. The exact opposite is happening in the industry, where software and products fight over the attention of users, under

the assumption that this increases profits. From experience, software like this becomes annoying and is prone to be rejected. Even so, products designed under this goal have some addictive ability, so people use other tools, control their usage. An example would be users utilizing productivity quantified self applications to control their own excessive usage of social media. An alternative to this problem would be to create "nice" products, which really support users so the users have the chance to enjoy the experience instead of being seduced into usage or becoming dependent for their self-image. The difference between the values implemented in contemporary quantified self applications to the values which programmers value themselves is striking. In Linux based operating systems the standard "one tool for one task" is emphasized and well-known. Programmers use such an approach to create software they use themselves. One reason is, swiss army knife software becomes nearly necessarily bad at one end or the other and Linux users do not want to be dependent on these suboptimal software parts. In contrast, when programming is done for mainstream usage, this standard does not seem to apply. Users are seduced to spend as much time at one platform as possible. The platform tries to become indispensable. It would be nice if development teams would hold up the standards they enjoy themselves on their platforms for the software they create for others. The idea to bind users to platforms is that companies can create financial profit this way. And at this point, the problem transforms from a software development problem to a capitalism problem. To create ethical software as described in this thesis, ethical software needs to become a value which creates capitalistic profit. Otherwise, the only way to ensure values would be laws such as the data EU General Data Protection Regulation. But this is another discussion.

7 Conclusion

In this thesis we elaborated ethical opinions about the development of quantified self devices. For this, we looked into the basic technological characteristic of tracking devices (user stories, sensors, feedback technology, and algorithmic knowledge creation) and created a concept about a smart dress with a scenario placed in the near future. Then, we summarized and applied ideas and concepts from sociology and psychology to understand how and why certain effects are to be expected. We applied these concepts to our dress scenario to gain understanding for risks and benefits. In the ethics chapter, we looked deeper which ethical values are affected, how they can be harmed by naive implementation of quantified self technology, and how certain values can be preserved. Along the way, we proposed several ideas how the implementation would need to look like, to preserve those values and help to maintain or increase human happiness.

The analysis of quantified self devices showed the self-improvement hypothesis as main motivation for users to track themselves. Next to self-optimization, self-exploration acts as motivator. Tracking is done in accordance to the users prevalent problem and can be of physical, emotional or behavioral nature. The analysis of the knowledge creation process of quantified self devices showed pitfalls, especially, the assumption, that the created knowledge is correct and neutral, and reflects the user in an undistorted manner. Also, the perception of context, as it is usually represented by an extensive set of sensors to track the environment, might not work as correctly as intended, since human tend to negotiate context with their environment, which is currently not supported in quantified self applications.

The change of behavior is the main goal of quantified self movement, when it comes to optimization. Hence, we looked into features of human nature which actually elicit actions in humans. Motivation is on of those basic features. The analysis of motivation showed that additional, extrinsic motivation can impede users on their way to fitness, health, or whatever individual goal they have, even if they were intrinsically motivated to begin with. Moreover, motivation can can from several sources, as personal, communal,

it can be pushed, and it can even be abused. We saw that personal motivation is based on many different individual goals of users. We showed that current devices, or our smart dress, cannot support them all. It is simply not feasibly to include a complete reflection of the real world, and to cover all possibilities. As a consequence, devices are prone to make mistakes during knowledge creation process, and at the same time, they promise neutral and objective feedback. Users themselves can react in two different ways to those mistakes, either they recognize the discrepancy and work their way around it, or they are pushed or motivated in behavior which hampers their progress or even risk their health. What users cannot do is changing their devices so that they perfectly fit to their lives. We showed that not only user domesticate their devices, but devices also domesticate users through the way they are handled. We see, that in the last step, users always need to adjust to the devices features, because they cannot change them. Even settings or open software does not change this kind of dependency. Another risk arises from the knowledge creation process. To support a fair sense of human self-efficacy, feedback from devices need to be sufficiently accurate, unbiased, and also not unfairly compared against peers or default values. This way, feelings of self-efficacy are not unnecessarily harmed. Self-regulation theory showed how people actually learn and chooses their actions. Quantified self devices affect this choosing by the feedback they display and the goals and standards they implement. The main insight from this theory is, that human self-regulation can be fragile. It can spin into downward spirals and lead to demotivation or even mental illness. Quantified self devices might not elicit those risks by themselves, but for the developers, the emotional context of the user is unknown. There are always risks, and development devices which elicit behavior change must be thought through carefully. Also the assumption that quantified self devices help people optimizing themselves cannot be backed by the analysis. In one third of all cases, we expect that feedback does not lead to the expected results.

The ethical reflection showed pitfalls but also brought up some ideas to improve the situation by changing critical assumptions about how quantified self devices are expected to work. The main question was, which kind of values are touched by quantified self, and which kind of changes have positive effect on users happiness. The analysis of the knowledge creation process showed a discrepancy between what people expect from feedback to maintain effort on their activity, and on the other hand, how people actually learn. The reflection of success would need to drop any curves of improvement, because people expect to see steady improvement to keep motivated, but this is not how effective learning looks like. Also, a different user story apart from self-optimization would be

needed. Instead, user stories should include critical thinking about whether the device is the right tool, and they should motivate experimentation and free reflection. This includes healthy skepticism about the results tracked by the devices, because they always include failures. Furthermore, often used incentives by producers to bind people to their products and spend extensive amounts of time there, should be discarded as a user story. This way, people can develop themselves and use those devices as a tool, only as long as they want and need to. Another ethical issue concerns trust and control over devices. To create a justified trust relationship between user and device, users need to be taken seriously as human beings and being included in development of devices. This way, some control over devices would shift towards the users. The users sense of autonomy would be strengthened. Further, the responsibility for the users wellbeing on very sensitive vulnerabilities (trackers are very private), need to be acknowledged by the producers to a larger extend than today. Not only minimum requirements of e.g., privacy, need to be implemented, but developers would need to "really" care for their users, in a similar way, as they would care, if the user revealed the same kind of vulnerability in a face to face situation. From the trust and control perspective, an user story for a device which maintains or improves happiness, would be not so far away from what is expected from healthy relationships to intimate partners. A device should support its users, let them breath and let them do their own thing, it should help with reflection or tips without dominating them, and it should know, when to withdraw. As risks exist in the usage of quantified self devices, we analyzed the role of consent. Informed consent protects a range of ethical values for the individual and helps to avoid abuse and domination. Quantified self devices influence physical and mental health. This means, they need to be assessed for risks on both topics. Their handling should be compared to other products or humans who influence peoples physical or mental health. In the current society, professionals for physical and mental health or fitness are required to have received training to avoid risking peoples health. Therefore, devices should at least be accompanied by professional advice, as long as they cannot give the same level of support. Also false promises needed to be minimized, similar as it is done for dietary products, for example, a certain weight loss should not be promised, not even implicitly. One risk of fitness tracker is, that they play a role in addictions. In an informed consent approach, this should be made aware before such a product is purchased, e.g., with warnings similar to gambling advertisement. Also leaflets could be included in the package, which do not only warn for technological induced risk (e.g., wrong handling can lead to electric shock), but all risks of usage, including physical and mental health risks. Also technological things can be done to minimize risks, especially from the product design. If numbers of steps per days would have a daily

maximum, it would be less easy to abuse them for unhealthy behavior. We analyzed how paternalistic quantified self and its environment is, and found out, that pushing the usage devices on people is not justified by the expected benefits, and also that devices which are used voluntarily can act paternalistic themselves through intensive nudging. The analysis of responsibility showed, that responsible product design includes the action of informing customers for shortcomings of the device and check its risks before it is launched. Privacy showed twofold effects on individual users and on society at a whole. Surveillance itself leads to problems in self-development of users, and the promise to not sell data does not change much. Privacy instead, provides breathing room for personal development. This has effects on the society because surveillance hampers individuals in their opportunities to privately reflect, experiment, and make mistakes. To protect the breathing room for self-development, there should be free and open spaces which are safe from surveillance. In these places other motivations of humans, e.g., altruism and curiosity can unfold themselves. These places should be safeguarded and provide places for intimacy, self-development, human interaction, research, reading, journalism, creativity, physical exercise and experience, religion and spirituality, and probably many more activities, which would be harmed by feelings of surveillance. Quantified self devices can also effect justice and fairness. The reason is, they are always implemented for a "large number of people". This implicitly risks that individuals, who are not thought of, are structural discriminated, especially, if results quantified self devices are used as base for further opportunities within a society. At last, we used the value sensitive design approach to examine the smart dress. Many of the upper risks were found again and several more improvement ideas. To protect privacy, tracking should be explicitly activated and only work for a limited amount of time and then turn off by default. To provide truth and knowledge, error ranges should be calculated and showed in any numerical feedback. To support autonomy, the user stories would need to have the goal of making people independent. Since users search for leadership, there could be at least some kind of configurable help-level and support to search for help by professionals. To support individual feelings of success, goals need to be at least personalizable and the device should not be allowed to judge.

The thesis opened up points of discussion to implement quantified self devices in critically different ways. It opposes the self-optimization hypothesis in its ability to support users or make them happy. This only works in very specific, very small cases. The goal of contemporary quantified self devices is, to include every aspect of human life, and to optimize them all, to create better people and increase the world's fairness. We showed

that the opposite is more likely. Values as truth, privacy, autonomy, and responsibility are crucial for the users' happiness and are mostly harmed by naive implementation of quantified self and its environment. Value sensitive approaches with the ideas offered in this work, would hopefully create complete different devices, a complete different environment, and different ways of distribution among society. Such an implementation would hopefully offer people more support to be themselves, minimize risks of harming physical and mental health, provide a live under less pressure, maintain a free and unmonitored society, and the devices could be used as simple tools instead as a way of living.

8 Outlook

This thesis was create under the goal of finding opinions and starting discussions. Respectively, several topics suggest further research. Since this thesis based most argumentations on theories, and their combination and continuation of thoughts, many of them offer starting points for concrete research. Main questions concern which role quantified self devices play in addiction or whether users actual feel the loosing of autonomy and other values. Also, research about the actual happiness of users of quantified self devices and a breakdown on the aspects of the devices would be interesting. This thesis focused mainly on the direct effects on users, and to a smaller part, on society. So, the effects on interpersonal relationship offer another point of future research. For example, the role of self-impression management and psychological effects of being seen in an un-euphemistic way. How would these things change the users? Would users try to become the perfect image or would they become accustomed to a more un-euphemistic self? Would such a society be more accepting or would mobbing and social exclusion increase? Self-impression management can also be supported from the technological side in very different ways. As filter beautify photos taken on smartphones, similar technology is thinkable for quantified self devices. From faking numerical results, to faking colors in the dress to create impressions purposely. Another point of thought, which can be continued, is that development of technology is always done for a large number of people. This leaves always many people out of the picture and creates injustice. Further research could include the question how technology can be more inclusive, not only by adding functionality, but maybe also by reducing devices to bare bone technology. Also, many critic points in this thesis do not only base in the field of technology but in broad social issues. It is more critique of capitalism that producers do not take responsibility for the effects of their products. Also, that their only goal is to increase their financial benefit and users are nudged to pay as much as possible. If not with their money, then with their information. The negotiation between economy and users or even between economy and legislation does not seem to be on the same eye level. Many problems could be influenced by changing that system. This topic is also something which was out of scope for this

thesis but is also broadly discussed in other sciences. How development of technology would fit in other kinds of more respectful and sustainable economic systems, would be a further step of research.

Bibliography

[1] *Yoga - Ahimsa - Wikipedia.* https://de.wikipedia.org/wiki/Ahimsa#Yoga. – [online; accessed 06-15-2019]

[2] *BITV 2.0 - Verordnung zur Schaffung barrierefreier Informationstechnik nach dem Behindertengleichstellungsgesetz* . https://www.gesetze-im-internet.de/bitv_2_0/BJNR184300011.html. – [online; accessed 05-05-2019]

[3] *Datenschutz-Grundverordnung - Wikipedia.* https://de.wikipedia.org/wiki/Datenschutz-Grundverordnung#Privacy_by_Design,_Privacy_by_Default. – [online; accessed 07-01-2018]

[4] *Double bind - Wikipedia.* https://de.wikipedia.org/wiki/Doppelbindungstheorie. – [online; accessed 08-15-2019]

[5] *Fitness trackers do not increase activity enough to noticeably improve health.* https://www.theguardian.com/society/2016/oct/04/fitness-trackers-do-not-increase-activity-enough-to-noticeably-improve-health. – [online; accessed 04-27-2019

[6] *Game - Wokamon.* https://play.google.com/store/apps/details?id=com.wokamon.android. – [online; accessed 2019-08-25]

[7] *Game - Zombies, Run!* https://play.google.com/store/apps/details?id=com.sixtostart.zombiesrunclient. – [online; accessed 2019-08-25]

[8] *Gaslighting - Wikipedia.* https://en.wikipedia.org/wiki/Gaslighting. – [online; accessed 08-19-2019]

[9] *Gefährder - Wikipedia.* https://de.wikipedia.org/wiki/Gef%C3%A4hrder. – [online; accessed 2019-06-09]

[10] *Polotech Agility.* https://www.ralphlauren.com/rlmag/polotech-agility.html. – [online; accessed 12-08-2018]

[11] *Pre-crime - Wikipedia.* https://en.wikipedia.org/wiki/Pre-crime. – [online; accessed 06-09-2019]

[12] *The Unseen - Somerset house.* http://seetheunseen.co.uk/project/somerset-house. – [online; accessed 01-25-2019]

[13] *Vorratsdatenspeicherung - Stehen alle Menschen unter Generalverdacht?* https://www.datenschutz.org/vorratsdatenspeicherung/. – [online; accessed 05-18-2019]

[14] *Öffentlicher Sektor: EU-Parlament beschließt Richtlinie für barrierefreies Web.* https://www.heise.de/newsticker/meldung/Oeffentlicher-Sektor-EU-Parlament-beschliesst-Richtlinie-fuer-barrierefreies-Web-3369292.html. – [online; accessed 05-05-2019]

[15] Ahad, Annie D. ; Lim, Syamimi Md A.: Convenience or nuisance?: The 'WhatsApp'dilemma. In: *Procedia-Social and Behavioral Sciences* 155 (2014), S. 189–196

[16] Asimakopoulos, Stavros ; Asimakopoulos, Grigorios ; Spillers, Frank: Motivation and user engagement in fitness tracking: Heuristics for mobile healthcare wearables. In: *Informatics* Bd. 4 Multidisciplinary Digital Publishing Institute (Veranst.), 2017, S. 5

[17] Bandura, Albert: Social cognitive theory of self-regulation. In: *Organizational behavior and human decision processes* 50 (1991), Nr. 2, S. 248–287

[18] Bhagwati, Sandeep ; Cossette, Isabelle ; Berzowska, Joanna ; Basanta, Adam ; Stein, Julian ; Browne, Joseph ; Bachmayer, Alexandra ; Del Tredici, Felix ; Albu, Sarah ; Giordano, Marcello u. a.: Musicking the Body Electric. (2016)

[19] Boyd, Danah: *What is Privacy?* http://www.zephoria.org/thoughts/archives/2014/09/01/what-is-privacy.html. – [online; accessed 05-18-2019]

[20] Broscheit, J.: *Air Mask.* https://csti.haw-hamburg.de/project/air-mask. – [online; accessed 05-08-2019]

[21] Buechner, J., Simon, J., and Tavani, H.T.: Re-Thinking Trust and Trustworthiness in Digital Environments. In: *Autonomous Technologies: Philosophical Issues, Practical Solutions, Human Nature: Proceedings of the Tenth International Conference on Computer Ethics: CEPE 2013* (2014), S. 65–79

[22] Butcher, J.N. ; Mineka, S. ; Hooley, J.M.: *Klinische Psychologie*. Pearson Deutschland, 2009 (PS - Psychologie)

[23] Cohen, Julie E.: What privacy is for. In: *Harv. L. Rev.* 126 (2012), S. 1904

[24] De Vries, Hein ; Mudde, Aart ; Leijs, Ingrid ; Charlton, Anne ; Vartiainen, Errki ; Buijs, Goof ; Clemente, Manuel P. ; Storm, Hans ; Navarro, Andrez G. ; Nebot, Manel u. a.: The European Smoking prevention Framework Approach (EFSA): an example of integral prevention. In: *Health education research* 18 (2003), Nr. 5, S. 611–626

[25] Dijk, Elisabeth T. Kersten-van ; Westerink, Joyce H. ; Beute, Femke ; IJsselsteijn, Wijnand A.: Personal Informatics, Self-Insight, and Behavior Change: A Critical Review of Current Literature. In: *Human–Computer Interaction* (2017), S. 1–29

[26] Dosenback, Kerstin: *Klassifikation von Audiosignalen mit Support Vector Machines*, Diplomarbeit, Hochschule für angewandte Wissenschaften Hamburg, Dissertation, 2007

[27] Dourish, Paul: What we talk about when we talk about context. In: *Personal and ubiquitous computing* 8 (2004), Nr. 1, S. 19–30

[28] Dunne, Anthony: *Hertzian tales: Electronic products, aesthetic experience, and critical design*. The MIT Press, 2008

[29] Duttweiler, Stefanie ; Passoth, Jan-Hendrik: Self-Tracking als Optimierungsprojekt? In: *Leben nach Zahlen. Self-Tracking als Optimierungsprojekt* (2016), S. 9–42

[30] Dworkin, Gerald: Paternalism. In: Zalta, Edward N. (Hrsg.): *The Stanford Encyclopedia of Philosophy*. Winter 2017. Metaphysics Research Lab, Stanford University, 2017

[31] Eyal, Nir: Informed Consent. In: Zalta, Edward N. (Hrsg.): *The Stanford Encyclopedia of Philosophy*. Spring 2019. Metaphysics Research Lab, Stanford University, 2019

[32] Froming, William J. ; Walker, G R. ; Lopyan, Kevin J.: Public and private self-awareness: When personal attitudes conflict with societal expectations. In: *Journal of Experimental Social Psychology* 18 (1982), Nr. 5, S. 476–487

[33] Gerrig, Richard J. ; Zimbardo, Philip: *Psychologie (18. Auflage)*. 2008

[34] Hermsen, Sander ; Moons, Jonas ; Kerkhof, Peter ; Wiekens, Carina ; De Groot, Martijn: Determinants for Sustained Use of an Activity Tracker: Observational Study. In: *JMIR mHealth and uHealth* 5 (2017), Nr. 10

[35] Hoerster, Norbert: Wie lässt sich Moral begründen? In: *Der Blaue Reiter* (2015), S. 28–31

[36] Holderegger, Adrian: Verantwortung. In: *Lexikon der Ethik* (2006), S. 394–403

[37] Hu, Jinlian ; Meng, Harper ; Li, Guoqiang ; Ibekwe, Samuel I.: A review of stimuli-responsive polymers for smart textile applications. In: *Smart Materials and Structures* 21 (2012), Nr. 5, S. 053001

[38] Höffe, Otfried: Einführung in Rawls' Theorie der Gerechtigkeit. In: *John Rawls: Eine Theorie Der Gerechtigkeit (Klassiker Auslegen) (German Edition)*. De Gruyter Akademie Forschung, 2013, S. 1 – 23

[39] Ichikawa, Jonathan J. ; Steup, Matthias: The Analysis of Knowledge. In: Zalta, Edward N. (Hrsg.): *The Stanford Encyclopedia of Philosophy*. Summer 2018. Metaphysics Research Lab, Stanford University, 2018

[40] Jakicic, John M. ; Davis, Kelliann K. ; Rogers, Renee J. ; King, Wendy C. ; Marcus, Marsha D. u. a.: Effect of Wearable Technology Combined With a Lifestyle Intervention on Long-term Weight Loss: The IDEA Randomized Clinical Trials. In: *JAMA* 316 (2016), 09, Nr. 11, S. 1161–1171. – URL `https://doi.org/10.1001/jama.2016.12858`. – ISSN 0098-7484

[41] Kluger, Avraham N. ; DeNisi, Angelo: The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. In: *Psychological bulletin* 119 (1996), Nr. 2, S. 254

[42] Leary, Mark R.: Making sense of self-esteem. In: *Current directions in psychological science* 8 (1999), Nr. 1, S. 32–35

[43] Lee, Felix: *Die AAA-Bürger*. `http://www.zeit.de/digital/datenschutz/2017-11/china-social-credit-system-buergerbewertung`. 2017. – [online; accessed 03-05-2018]

[44] Lee, Yoonmyung ; Bang, Suyoung ; Lee, Inhee ; Kim, Yejoong ; Kim, Gyouho u. a.: A modular 1 mm ^{3} die-stacked sensing platform with low power I ^{2} C inter-die communication and multi-modal energy harvesting. In: *IEEE Journal of Solid-State Circuits* 48 (2013), Nr. 1, S. 229–243

[45] Lupton, Deborah: Self-tracking modes: Reflexive self-monitoring and data practices. (2014)

[46] Mämecke, Thorben: Benchmarking the Self. In: *Leben nach Zahlen: Self-Tracking als Optimierungsprojekt?* 10 (2016), S. 103

[47] Marder, Ben ; Joinson, Adam ; Shankar, Avi ; Houghton, David: The extended 'chilling' effect of Facebook: The cold reality of ubiquitous social networking. In: *Computers in Human Behavior* 60 (2016), S. 582–592

[48] Maslow, A: *Motivation and Personality*. 2. Harper & Row Publishers, 1970

[49] Müller, Larissa ; Bernin, Arne ; Luck, Kai von ; Kamenz, Andreas ; Ghose, Sobin ; Wang, Qi ; Grecos, Christos ; Vogt, Florian: Enhancing exercise experience with individual multi-emotion provoking game elements. In: *Computational Intelligence (SSCI), 2017 IEEE Symposium Series on* IEEE (Veranst.), 2017, S. 1–8

[50] Pieper, Annemarie: Warum wir moralisch handeln müssen. In: *Der Blaue Reiter* (2015), S. 12–17

[51] Prochaska, James O. ; Velicer, Wayne F.: The transtheoretical model of health behavior change. In: *American journal of health promotion* 12 (1997), Nr. 1, S. 38–48

[52] Schollas, Sabine: Self-Tracking und Gamification als Mittel der Kundenbindung und des Marketings. In: *Leben nach Zahlen: Self-Tracking als Optimierungsprojekt?* 10 (2016), S. 87

[53] Selvaraj, Jerritta ; Murugappan, Murugappan ; Wan, Khairunizam ; Yaacob, Sazali: Classification of emotional states from electrocardiogram signals: a non-linear approach based on hurst. In: *Biomedical engineering online* 12 (2013), Nr. 1, S. 44

[54] Simon, Judith: Values in Design. In: *Handbuch Medien-und Informationsethik*. Springer, 2016, S. 357–364

[55] Simpson, Courtney C. ; Mazzeo, Suzanne E.: Calorie counting and fitness tracking technology: Associations with eating disorder symptomatology. In: *Eating behaviors* 26 (2017), S. 89–92

[56] Spiekermann, Sarah: *Ethical IT Innovation: A value-based system design approach*. CRC Press, 2015

[57] Stangl, W.: *Bedürfnisaufschub*. https://lexikon.stangl.eu/2147/beduerfnisaufschub/. – [online; accessed 06-28-2019]

[58] Stangl, W.: *Extrinsische Motivation*. http://lexikon.stangl.eu/1951/extrinsische-motivation/. – [online; accessed 12-15-2018]

[59] Stangl, W.: *Fear Of Missing Out*. http://lexikon.stangl.eu/17010/fear-of-missing-out-fomo/. – [online; accessed 02-09-February-2019]

[60] Stangl, W.: *Gerechtigkeit*. http://lexikon.stangl.eu/21388/gerechtigkeit/. – [online; accessed 01-29-2019]

[61] Stangl, W.: *Intrinsische Motivation*. https://lexikon.stangl.eu/1949/intrinsische-motivation/. – [online; accessed 06-18-2019]

[62] Stangl, W.: *Motivation*. http://lexikon.stangl.eu/337/motivation/. – [online; accessed 12-15-2018]

[63] Stangl, W.: *Selbstbild*. https://lexikon.stangl.eu/8083/selbstbild/. – [online; accessed 03-09-2019]

[64] Stangl, W.: *Selbstkontrolle*. https://lexikon.stangl.eu/9813/selbstkontrolle/. – [online; accessed 06-28-2019]

[65] Vuojärvi, Hanna ; Isomäki, Hannakaisa ; Hynes, Deirdre: Domestication of a laptop on a wireless university campus: A case study. In: *Australasian Journal of Educational Technology* 26 (2010), Nr. 2

[66] Wan, Chin-Sheng ; Chiou, Wen-Bin: Psychological motives and online games addiction: Atest of flow theory and humanistic needs theory for taiwanese adolescents. In: *CyberPsychology & Behavior* 9 (2006), Nr. 3, S. 317–324

[67] Weiser, Mark: The computer for the 21st century. In: *Scientific american* 265 (1991), Nr. 3, S. 94–104

[68] Wiegerling, Klaus: *Philosophie intelligenter Welten*. Wilhelm Fink Verlag, 2011

A Das intelligente Kleid

Sally wacht auf und wie üblich fällt ihr Blick zuerst auf den Wecker. Schon 20 nach 6, und die bleierne Müdigkeit mischt sich mit einer leichten Panik. Sie hat relativ wenig Zeit, bis sie um halb 9 im Büro sein muss. Der Wecker hat nicht mehr gewartet bis sie sich in einer Leichtschlafphase befindet, sie wäre sonst zu spät auf Arbeit gewesen. Sie sollte früher ins Bett gehen, ärgert sie sich, dann schafft sie es zur nächsten Leichtschlafphase.

Nach dem Duschen macht sich Sally Frühstück. Zuckerfreies Müsli, Obst, Kaffee, das Übliche. Aufgrund ihres Bewegungsmangels in einem Bürojobs wurde ihr gesundes Frühstück ans Herz gelegt. Es gab sogar eine offizielle Notification dafür. Seitdem sieht sie auch ständig Werbung für Bio-Produkte. Seit die Krankenkassen mit den Smart-Clothing-Anbietern zusammenarbeiten, sind die Preise für gesunde Produkte auch deutlich gesunken. Wahrscheinlich ist die Nachfrage gestiegen, so erklärt Sally sich das. Gesundheit kann ja nicht schaden, also warum beschweren. Und irgendwie ist sie auch ein wenig stolz, dass sie den Übergang von Nutella-Toast auf Früchtemüsli hingekriegt hat.

Im Büro ist Hektik ausgebrochen. Die Deadline naht, alles muss gleichzeitig passieren, und zu allem Überfluss spuckt die Kaffeemaschine momentan nur noch Decaf aus. Sie hat die Privacy-Option von ihrem Kleid so gesetzt, dass es mit den bürointernen Geräten kommunizieren darf, um ihren Arbeitsalltag zu erleichtern. Für Türöffner, Kalender, und Bewegungstracking findet sie das praktisch, aber offenbar ist auch erhöhter Koffeinkonsum mit ihrem Gesundheitsprogramm nicht vereinbar. Zum Glück ist Sallys Kollege so freundlich, ihr eben einen echten Kaffee aus der Maschine zu ziehen.

In der monatlichen Teambesprechung ist aufgekommen, dass Sally und ihre Kollegen im Vergleich zu den anderen Büros der Umgebung relativ wenig Sport- und Gesundheitsmanagement betreiben. Der firmenübergreifende Durchschnittswert der *Healthpoints* hat sich seit dem letzten Monat noch einmal leicht verschlechtert.

Um Stress zu bekämpfen, und Krankheiten vorzubeugen haben die Krankenversichererungen die Healthpoints eingeführt. Diese kann man bei den verschiedensten Anlässen sammeln. Von gesundem Essen, über Anwendung von Stressmanagement-Techniken, bis hin zu sportlichen Aktivitäten. Wer viele Healthpoints hat, kann seine seinen monatlichen Krankenkassenbeitrag reduzieren. Auch Arbeitgeber erhalten die Ermäßigung auf die Krankenkassenbeiträge. Auf diese Weise wird motiviert, Arbeitnehmern wie Sally eine gesunde Umgebung zur Verfügung zu stellen. Es soll auch die Gemeinschaft innerhalb der Firmen stärken, da sich die Menschen wohler fühlen und gemeinsam an ihrer Gesundheit arbeiten.

Sally hält das für eine gute Sache und nimmt auch gerne die ermäßigten Krankenkassenbeiträge mit. Sie hat daher ihr Profil so eingestellt, dass ihr Kleid sie regelmäßig an Bewegung erinnert, und ihr eine Warnung gibt, wenn sie gestresst ist.

Als ihr Kleid ihr ein kleinen Nudge am linken Oberarm gibt, horcht Sally in sich rein. Sie fühlt sich tatsächlich etwas aufgekratzt und gestresst. Leichte Rückenschmerzen vom Bürostuhl sind auch da. Sie legt ihre Arbeit beiseite und zieht sich für eine Fünf-Minuten-Meditation in den Self-Management-Raum zurück. Hinter ihr klickt die Tür auf *Besetzt*. Sie geht an den Balanceboards, dem Laufband, dem Boxsack und den Meditationskissen vorbei und stellt sich ans Fenster. Sie lauscht auf ihren Atem, spürt die Füße, die Beine, den Körper und die Schultern. Bei ihrem Gesicht angekommen bemerkt sie wie zusammengezogen ihre Stirn ist. Dann entspannt sich ihr Gesicht wie von selbst. Als sie die Augen wieder öffnet, sind die Buntanteile in ihrem Kleid eine Nuance heller geworden. Geht doch, denkt sie erleichtert. Wenigstens hat sie ihren Anteil getan, kommt etwas bitterer hinzu, als sie auf dem Weg zurück zum Schreibtisch einen Kollegen trifft. Er hält einen Pizzakarton in der Hand und das wird der Healthpoint-Firmenbilanz sicher nicht gut tun.

An diesem Abend kommt sie erschöpft bei ihr vor der Haustür an. War viel Stress gewesen heute. Alle laut, alle hektisch, und trotzdem kein bisschen sportlich. Sally nimmt die Treppe, statt dem Aufzug, ihr fehlen noch ein par Schritte bis zu ihrem Tagesziel. Wenn sie heute abend beim Zähneputzen auf der Stelle joggt, wird sie es aber noch schaffen.

Am nächsten Tag hat Sally frei, beziehungsweise, sie muss was für die Uni machen. Wo geht das besser als im Cafe? Mit dem Bus währen es 10 Minuten aber sie hat sich angewöhnt solche Strecken zu Fuß zu laufen. Wenn dabei der Puls hoch genug ist, wird es als *active phase*, also Sport, in ihren Gesundheitslog eingetragen. Sie hat auch gemerkt, dass wenn der Puls aus anderen Gründen hochgeht, zum Beispiel, wenn es im Bus voll ist,

und unangenehme Menschen hinter ihr stehen, es schnell als active phase gewertet wird. Demnach, wie schnell sich der Bus durch den zähen Stadtverkehr schiebt, interpretiert das System die Bewegung als Jogging- oder Fahrradstrecke. Das kann praktisch sein, wenn man gerade keine Lust auf Sport hat, aber auf die unangenehmen Menschen im Bus kann sie auch verzichten. Lieber ein kleiner Stadtspaziergang. Für die Uni schafft sie heute nicht viel. Sie ist unkonzentriert und geht irgendwann einfach nachhause.

Im Laufe des Nachmittags wird Sally eine Doctors-Notification zugeschickt, in der vor einer aufkommenden Erkältung gewarnt wird. Das kennt sie schon. Das passiert jeden Monat einmal, ziemlich direkt 3 Tage vor ihrer Menstruation. Sie fragt sich dann, wann die Systeme lernen, dass sie auch von Frauen benutzt werden und geht Tampons kaufen.

Abends ist Sally noch mit ihrer Freundin Theresa zum Yoga verabredet. Dafür nutzt sie ihre smarte Sportkleidung, die noch etwas praktischer ist als das Kleid. Der Fernseher ist eingeschaltet, um 20 Uhr geht's los. Die Yogalehrerin macht vor, und spricht die Übungen durch. Über die Kleidung kann die Lehrerin auch die Positionen der einzelnen Teilnehmer sehen und korrigieren. Sally ist froh, dass sie selbst nicht mehr per Kamera übertragen wird. Sie hat keine Lust vorher aufräumen zu müssen. Die Kamera kann man jetzt nur noch freiwillig einschalten. Seit die Kurse zuhause stattfinden, sind sie auch generell kostenlos geworden. Sally mag das mit dem Yoga zuhause, aber Theresa ist häufig genervt davon. Viele Korrekturen, die die Kursleiterin an alle durchgibt, gehen vor allem auf Theresas Leistungen zurück, die deutlich unter dem der anderen Kursteilnehmer liegen. Man kann auch nach dem Kurs seine eigenen Leistungen (ein berechneter Quotient über die richtigen Bewegung) gegen die der anderen Kursteilnehmer vergleichen, und Theresa hat es einfach satt immer die Schlechteste zu sein. Ihr nicht-richtig-mitmachen liegt auch daran, dass es Theresa häufig nicht besonders gut geht. Wenn sie sich dann noch dazu motivieren muss genauso gut zu sein, wie die anderen Kursteilnehmer, fühlt sie sich benachteiligt. Als sie ihre erste smarte Kleidung bekommen hat, war sie noch sehr motiviert gewesen, und hat sehr viele Bewegungspunkte gesammelt. Sie konnte damals kaum an was anderes denken als abzunehmen, hat viel zu wenig gegessen und ständig Sport gemacht. In der Zeit hat sie sehr viel Gewicht und Muskeln verloren, und seitdem sind ihr Anstrengungen einfach schnell zu viel. Sie hat dann schlussendlich den täglichen Bewegungszähler komplett deaktiviert. Die einzige Möglichkeit jetzt noch an den Bonus für Krankenkassengebühr zu kommen, sind die Sportkurse. Die Gebühr ohne Bonus kann sie sich nicht leisten. Also macht sie das Minimal-Programm, einen Anfänger-Yoga-Kurs pro Halbjahr, und zwar so unmotiviert, dass es gerade noch reicht keine *fail*-Note zu kassieren. Sally hat sich vor allem zu Theresas Unterstützung für diesen Kurs angemeldet,

aber eigentlich ist ihr der jetzt schon zu leicht. Ihr Bewegungsquotient liegt auch immer im oberen Drittel des Kurses. Sie will daher nächstes Halbjahr den fortgeschrittenen Kurs besuchen und hofft, dass Theresa irgendwie damit zurecht kommt.

Erklärung zur selbstständigen Bearbeitung einer Abschlussarbeit

Gemäß der Allgemeinen Prüfungs- und Studienordnung ist zusammen mit der Abschlussarbeit eine schriftliche Erklärung abzugeben, in der der Studierende bestätigt, dass die Abschlussarbeit „– bei einer Gruppenarbeit die entsprechend gekennzeichneten Teile der Arbeit [(§ 18 Abs. 1 APSO-TI-BM bzw. § 21 Abs. 1 APSO-INGI)] – ohne fremde Hilfe selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt wurden. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter Angabe der Quellen kenntlich zu machen."

Quelle: § 16 Abs. 5 APSO-TI-BM bzw. § 15 Abs. 6 APSO-INGI

Erklärung zur selbstständigen Bearbeitung der Arbeit

Hiermit versichere ich,

Name: _____

Vorname: _____

dass ich die vorliegende Masterarbeit – bzw. bei einer Gruppenarbeit die entsprechend gekennzeichneten Teile der Arbeit – mit dem Thema:

Ethical Reflections on Quantified Self Devices and their Effects on Humans

ohne fremde Hilfe selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt habe. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter Angabe der Quellen kenntlich gemacht.

_____	_____	_____
Ort	Datum	Unterschrift im Original