Aalto University
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FACILITATING HEALTH BEHAVIOR CHANGE WITH WEARABLE TECHNOLOGY

Bridging the gap between recording data and changing habits

Master's Thesis
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Abstract

Modern day health problems, such as sedentary behavior, inactivity, and poor sleeping habits are challenging the lives of both individuals and health care systems around the world. Wearable technologies, which use sensor technology to track various health parameters, provide new ways for monitoring personal health. Ideally, the use of wearables would mitigate these health issues. However, while the popularity of wearable devices has increased rapidly during the past years, little attention has been paid to the health effects of using the technology. Thus, this thesis studies the perceived health benefits of using wearable technology to analyze whether wearables are used for simply recording information or, in fact, changing health behavior.

The empirical part of the thesis was conducted as a qualitative study using semi-structured interviews, to understand the users' experiences of using wearable technology. The interview data were analyzed thematically with the help of an analytical framework that was developed for the thesis.

The findings suggest that the use of wearable technology increases the users' awareness of their current health status and habits, which further results in changes in health behavior, provided that the users are motivated to change their behavior. The perceived health benefits of wearable technology use include increased activity, better sleep, and smarter training and recovery behavior.

Keywords wearable technology, heath behavior change, self-tracking

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Tiivistelmä

Nykypäivän terveyshaasteet kuten liika istuminen, liikkumattomuus ja huonot nukkumistavat haastavat niin yksilöiden kuin terveydenhuoltojärjestelmien toimintaa ympäri maailman. Puettavat teknologiat, jotka hyödyntävät erilaisia sensoreita moninaisten terveysparametrien seuraamiseen, tarjoavat uusia tapoja henkilökohtaisen terveyden seurantaan. Ihanteellisessa tilanteessa puettavien teknologioiden käyttö lieventäisi edellä mainittuja terveysongelmia. Vaikka viime vuosina laitteiden suosio on kasvanut nopeaan tahtiin, toistaiseksi paljoakaan huomiota ei ole kiinnitetty puettavan teknologian käytön terveysvaikutuksiin. Tämä tutkielma selvittää puettavien teknologioiden käytöstä koettuja terveyshyötyjä. Tutkielman tarkoituksena on selvittää, käytetäänkö puettavia teknologioita lähinnä terveystietojen tallentamiseen vai onko mittaamisella varsinaisia vaikutuksia ihmisten terveyskäyttäytymiseen.

Tutkimus toteutettiin laadullisena tutkimuksena ja siinä käytettiin puolistrukturoituja haastatteluja tiedonkeruumenetelmänä. Haastatteluiden päämääränä oli lisätä ymmärrystä ihmisten kokemuksista puettavien teknologioiden käytöstä. Haastattelut analysoitiin temaattisesti hyödyntäen analyyttistä kehystä.

Tutkimustulokset osoittavat, että puettavan teknologian käyttö lisää käyttäjien tietoisuutta omasta terveydestä ja tavoista, mikä edelleen johtaa terveyskäyttäytymisen muutoksiin, edellyttäen että käyttäjät ovat motivoituneita muuttamaan käyttäytymistään. Teknologian käytöstä koettuja terveyshyötyjä ovat lisääntynyt aktiivisuus, parempi uni, sekä viisaampi toiminta harjoittelun ja palautumisen suhteen.

Avainsanat puettava teknologia, käyttäytymisen muutos, itseseuranta

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I would like to thank my faithful study companion, Lenni. Your unwavering presence brought joy and comfort during long hours of research and writing, making this project a lot less dreadful.

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Table of Contents

List of Tables

List of Figures

List of Definitions

Health = A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 1948).

Health behavior = The behavior and choices of an individual related to health issues (Duodecim, 2016).

Wearable (health) technology = non-invasive, commercially available wearable devices that include fitness tracking features to collect a broad range of data, such as, movement levels, sleep, steps, and heartbeat.

1 Introduction

Inactivity, sedentary living, and poor sleeping habits are global health problems affecting not only the health of individuals but also the burden of healthcare systems around the world. In Finland, two-thirds of the population do not meet the health exercise recommendations, while a quarter do not get a sufficient amount of sleep (THL, 2017). In service research, health and wellbeing have emerged as one of the most notable research topics (Lin & Windasari, 2019).

Wearable technologies can be seen as a possible part of the solution for the aforementioned problems as there has been a growing trend in using wearables and other self-tracking devices for monitoring and maintaining personal health (Lin & Windasari, 2019). Wearables, which use sensor technology to track various parameters such as steps, sleep, and heart rate, provide new ways of collecting and analyzing personal health data (Rieder et al., 2021). Wearables not only collect the data, but also produce clear visualizations and key performance indicators on that data (Feng et al., 2021). Incorporating a number of behavior change techniques, wearables are marketed as tools to motivate people to improve their health (Rieder et al., 2021; Phillips et al., 2018).

Despite the growing interest in self-tracking with wearable technology, there is little evidence of wearables bringing about sustainable behavior change (Lehrer et al., 2021). Moreover, most research on the topic has focused on motivations rather than actual lifestyle changes (Liang & Ploderer, 2016). Patel et al. (2015) note that there is still a large gap between recording information and changing behavior. Although more and more personal health data is recorded every year with wearable technology, it is yet unknown how that data is impacting the health and wellbeing of individuals.

Prior research suggests that wearable technology can be effective for attaining positive health outcomes in the short-term. However, most studies have been limited to studying clearly defined user groups, such as senior citizens or people with a specific health condition. Therefore, Jin et al. (2020) suggest that future studies should focus on “regular users”. Moreover, many previous studies on wearable technology have used physical activity (PA) as the sole determinant of people’s health. In this thesis, health and wellbeing will be examined from a broader perspective, including not only PA but subjective wellbeing, quality of life, and sleep. This thesis will focus on everyday users of wearable technology to discover its impact on their overall health and wellbeing.

1.1 Research problem and objectives

The purpose of this thesis is to explore how people use wearable technology and what are the perceived health benefits of collecting personal health data with wearable technology. The main objective of this thesis is to research the effect of wearable technology on the users' health and wellbeing. More specifically, it aims to discover whether consumer wearables merely increase users' awareness about their health or, in fact, help them improve their health and wellbeing in the long run. The research questions for this research are presented as follows.

RQ: How do consumer health wearables affect the health and wellbeing of users?

Sub RQ: Does the use of wearables increase the awareness of users' current health behavior, and if so, does this facilitate health behavior change?

1.2 Thesis structure

The thesis is structured in the following way. In chapter one, the thesis topic is introduced with background information and motivation for the research. The research problem and objectives are then discussed.

The previous literature on the topic is discussed in chapter two. The chapter begins by introducing commercial wearable technology, after which the previously researched health outcomes of wearable technology use are discussed. The validity of the technology as well as its different roles are then discussed. The chapter ends with a discussion on behavior change techniques that have been incorporated in wearable technology.

The theoretical grounding for the research is discussed in chapter three. To better understand how wearable technology use may affect an individual's health behavior, the notion of behavior change support systems (BCSS) and related behavior change theories are discussed. This forms the theoretical base for the thesis. The analytical framework for the thesis is presented at the end of chapter three.

Different research methodologies are covered in the fourth chapter. In this chapter, the reasons for the selected methods for data collection and analysis are discussed. Research ethics are discussed in this chapter.

The research findings are discussed in chapter five. The findings are discussed in themes that were formed based on the interview topics and other relevant themes that arose during the interviews.

In the sixth chapter, the main research findings are further discussed and compared to earlier research findings.

The final chapter for this thesis focuses on the limitations and final conclusions of the thesis. Based on the limitations, some suggestions for future research on the topic are given.

2 Literature review

The aim of the literature review is to provide a brief summary of the theories and prior research related to the research problem (Hakala, 2017). For the researcher, the purpose of conducting a literature review is to discover possible research gaps for further research, and to reach a comprehensive base for conducting their own research.

The literature review begins with an introduction to commercial wearable technology. The main findings of prior research on the health outcomes of wearable technology are then discussed. In this chapter, the validity of wearable technology as well as the different roles the technology plays in people's lives are also covered. The chapter ends with a brief introduction to behavior change techniques in wearables. For better clarity and easier readability of the thesis, the theoretical base and prior research related to the selected theories are separated from the literature review and are covered in detail in the third chapter.

2.1 Commercial wearable health technology

Wearable technologies can be defined as electronic devices consisting of physical and digital artifacts that can be integrated into clothing and other accessories that can be comfortably worn on the body (Wright & Keith, 2014; Rieder et al., 2021). In addition to the capability of being worn, wearable technologies differ from other technologies and other wearable items by their capability of integrating information technology to autonomously communicate and process information on the go (Kalantari, 2017). Wearable devices use sensor technology to track various parameters such as steps, sleep, heart rate, as well as a range of different activities (Rieder et al., 2021). The data collected by the sensors is paired with analytics or machine learning applications to generate aggregations to be displayed to the user either directly on the device interface or via computer or smartphone applications (Rieder et al., 2021).

Wearable technologies cover a large variety of devices and use purposes. The most common types of devices include smart watches and personal fitness trackers, which are available as watches, wrist bands, bracelets, clip-ons, and even rings. Other types of devices include, for instance, headbands and smart glasses, as well as smart clothing, such as t-shirts with built-in sensors. Although wearable technologies generally refer to devices that can be worn on the body and may be easily changed or taken off, they also include more invasive innovations, such as smart tattoos or micro-chips that are implanted in the body (Wright & Keith, 2014).

A number of taxonomies have been proposed in prior research to classify wearable devices into different groups. Wearables can be classified based on product forms (e.g., hand-worn, or foot-worn) and product functions (e.g., health and wellness) (Kalantari, 2017). A more extensive categorization by Park et al. (2014) classifies wearable devices based on functionality (single or multi-functional), deployment mode (invasive or non-invasive), communication mode (wired or wireless), disposability, type (active or passive), and field of use (health, military, entertainment, etc.). The purpose of such taxonomies is to identify the currently available devices so that appropriate ones can be selected as well as to identify opportunities for future development and design of wearables for areas that need to be further addressed (Park et al., 2014).

Since there exist a number of devices and classifications for wearables, there are also a number of terms that are used for the concept of wearable technologies. Given the dominance of fitness related wearables on the market, the terms “wearables”, “wearable devices”, “activity/fitness trackers”, and “activity monitors” are among the most common terms used in previous research and are often used interchangeably. Moreover, the terms “self-tracking” and “quantified self” appear repeatedly in wearable technology research. Self-tracking refers to the action of improving one’s knowledge about their own health and wellbeing by keeping track of various health indicators either via mobile and wearable technology, or on paper (Liang & Ploderer, 2016). The term “quantified self” generally refers to the community of early adopters of self-tracking technologies (Liang & Ploderer, 2016). Furthermore, Jin et al. (2020) note that care should be taken when using the various terms and, for instance, when generalizing findings on wearable technology to the domain of fitness tracking technology. They continue that fitness trackers are one type of wearable technology, but not all wearables include fitness tracking features. Therefore, when conducting research for this literature review it is important to pay attention to what types of wearables are being studied in each research. Similarly, self-tracking and the quantified self include not only tracking via wearables but also via mobile applications or even manual tools.

Wearable technology for personal health tracking includes a variety of different devices that have various features. Moreover, based on their functions, different wearable devices can be optimized for different types of tracking. Some trackers, such as the WHOOP band, offer some of the best features and metrics for monitoring recovery, while the Garmin Instinct Solar watch offers great features for recording hiking data, for instance. Many of the

Fitbit wearable wristbands, on the other hand, are well designed for tracking steps and other everyday activity data.

The focus of this thesis is to study the impact of wearable technology on people's overall health behavior and wellbeing. Consequently, for the purpose of this thesis, the previously mentioned terms of wearable technology will be used interchangeably to cover non-invasive, commercially available wearable devices that include fitness tracking features to collect a broad range of health data, such as, movement levels, sleep, steps, or heartbeat. The thesis will not focus on a single type or brand of wearable. Instead, the goal of the research is to include a variety of different types of wearables that track various health metrics discussed above.

Wearable technologies can bring about a number of benefits not only for individuals but societies and businesses as well (Kalantari, 2017). The following sub-section will focus on the researched outcomes of using wearable technology.

2.2 Health outcomes of wearable technology use

Over the past decade, wearable technologies have gained increased attention from both consumers and researchers. Wearable technologies hold much promise for promoting health behavior change and they have been considered as a possible piece in the fight against global health problems such as inactivity, sedentary living, and poor sleeping habits (Patel et al., 2015). Wearables have become more and more popular, and for instance from 2014 to 2018 the wearable technology market more than tripled (Rieder et al., 2021). However, according to Piwek et al. (2016), a third of all wearable technology users discontinue usage after only six months, and up to half discard the devices within a year from adoption. Not surprisingly, much of the previous research on wearable technology has focused on the issues related to wearable design and the drivers and motivations for wearable adoption. In recent years, the behavioral aspects of wearable technology have received an increasing amount of interest as researchers have identified that it is unknown to what extent these technologies affect the health and behavior of individuals (Sullivan & Lachman, 2017) and how useful these technologies are for sustained behavior change (Piwek et al., 2016). Patel et al. (2015) state that while the popularity of wearables is increasing, there is still a big gap in research between recording information and actual behavioral changes. Further studies are needed to understand the health outcomes of wearables (Phillips et al., 2018). The focus of this thesis is to address this research gap.

Behavior change is a long-term process as opposed to a one-time modification in one's habits. Patel et al. (2015) note that health-related behaviors can lead to meaningful improvements in population health only if the behaviors are sustained. Nonetheless, much of the existing research focusing on the outcomes of wearable technology have been short-term in nature.

Prior research suggests that wearable use can be effective in the short-term for reaching positive health outcomes, such as increasing physical activity (Brickwood et al., 2019; Tang et al., 2020) and weight loss (Cheatham et al., 2018). Nonetheless, most of the prior studies have been short-term control studies to explore health variables before and after using a wearable. For instance, Frank et al. (2016) studied the use of wearable devices to monitor and detect potential changes in the activity levels and behavior of students at a high school. The use of wearable technology was effective for decreasing the time spent sitting and increasing the time spent moving during a school week. Similarly, Tang et al. (2020) found that wearable tracker use had a modest positive effect for increasing physical activity in the short term among healthy adults. Moreover, Stiglbauer et al. (2019) studied the effects of wearable use by conducting a two-week long control study among university students. They examined the technology's impact on several health indicators, specifically focusing on health consciousness, physical health, and psychological wellbeing. They found that the use of wearable technology increased the students' perceived physical health and partially improved their psychological wellbeing. On the contrary, health consciousness, i.e., "the extent to which health concerns are integrated into a person's daily activities" (Jayanti & Burns, 1998, p.10, cited in Stiglbauer et al., 2019) was increased among both wearable users and non-users, suggesting that simply asking questions about the participants' health may increase their health consciousness. Although the findings of the aforementioned studies are promising, it is impossible to disclose any long-term behavioral outcomes from studies with such limited scope and timeframe.

Wearable technologies' effect on overall health, including subjective wellbeing, perceived quality of life, and other psychological factors, is even less clear. Jin et al. (2020) studied the outcomes of self-tracking technology, and while they concluded that the tracking positively impacted users' motivations to engage in physical activities as well as increased their actual physical activity levels, the impact on overall well-being remained unclear. The research revealed mixed findings on users' task-experience, e.g., whether users enjoy activities more with or without the presence of a tracker. This finding suggest that the use of wearable technology could actually have a negative health effect by making physical activity

less enjoyable for people. The finding is alarming as this could lead to people being even less active and more sedentary than before – making wearable technology a cause, not a solution, for the global problem. Furthermore, there is evidence that self-tracking technologies can have both positive and negative impacts on users' subjective wellbeing (Jin et al., 2020). The study by Frank et al. (2016) yielded similar results, indicating inconclusive findings on the wearables' effect on the students' evaluations on focus, productivity, energy, and emotional state. Wu et al. (2016) continue that continuous monitoring of activities may impact a person's mental and physical health in a negative way and could even lead to depression or mental stress.

Wu et al. (2016) state that the health benefits of wearable technology are driven by long-term usage of the devices – the longer a person continues to use a wearable, the more likely they are to experience improvements in health and wellbeing. On the contrary, Lin & Windasari (2019) found that the intention to continue wearable use does not directly translate to improvements in the quality of life. They note that improvements in wellbeing are impacted by high self-efficacy, while intentions of continued use of wearables is affected by high engagement with the device. As a result, the intention to continue use does not necessarily result in changes in wellbeing. Another way to describe this is that people may experience positive health effects even from short-term wearable use – the key determinant being the individual's level of self-efficacy. The importance of self-efficacy will be further discussed in part 3.1.1 of the thesis.

2.3 Validity of wearable technology

The accuracy and validity of wearable tracking technology is an important issue to consider for the investigation of long-term health behavior changes. If the data provided by wearable devices is inaccurate and inconsistent, it is essentially useless for health behavior change.

Sullivan & Lachman (2017) note that wearable tracking offers many benefits compared to subjective self-reporting, which has been the main instrument of health behavior change studies in the past. They continue that subjective activity tracking is unreliable not only because people often overestimate the intensity and time spent of an activity, but also underestimate many everyday activities such as running errands. Objective and often round-the-clock tracking offered by wearable tracking is therefore better – it remembers to record data even if the user does not.

There are a multitude of studies reporting the validity of wearables. Previous research indicates that wearables are accurate and consistent especially for measuring step counts,

however, estimates of energy expenditure are much more inaccurate (Sullivan & Lachman, 2017). Evenson et al. (2015) studied the reliability (i.e., consistency of results within the same device) and validity (i.e., the accuracy of results compared to a criterion measure such as polysomnography for sleep) of a number of consumer wearable trackers. The review indicated high validity for steps, less so on distance and physical activity, and low validity for energy expenditure and sleep. Furthermore, the research showed that trackers overestimated total sleep time and sleep efficiency, while wake after sleep onset was underestimated compared to metrics from polysomnography. In other words, the devices gave overly positive evaluations for the users' sleep metrics.

Since there are a number of wearable devices with a variety of algorithms to provide information, the activity data may differ slightly from brand to brand. One problem with this is that the algorithms that transform raw data into meaningful information about the user's activity and health are usually not publicly available (Sullivan & Lachman, 2017). Nonetheless, data consistency is the most important factor for the purpose of health behavior tracking and analysis. For instance, if a person was to wear multiple wearable devices, such as a GPS watch and a smart ring, and recorded step counts with both devices, it is important that the difference in daily steps between the devices is consistent. Therefore, if the ring were to record 10% more steps than the watch, the ratio should stay at that level any given day. Thus far there is also no consensus on the best placement for a wearable device for most accurate results (Sullivan & Lachman, 2017). Nonetheless, there is evidence that consumer wearables are reliable enough for regular consumers' activity and health tracking purposes (Sullivan & Lachman, 2017).

2.4 The different roles of wearables

As discussed earlier in the thesis, there are several different types of wearable devices available for consumers on the market. Moreover, different devices can have different roles in a person's self-tracking: a person might use a smart ring to measure sleep and a GPS watch to measure running and other physical activities.

Lyall & Robards (2018) argue that a wearable can have a triple role: a device can act as a 'tool, a toy, and a tutor'. The 'tool' role refers to using the wearable as a means to an end, such as to develop a statistical record over many years of running. As a 'toy', the user focuses on novel and gamified elements of the wearable, instead of using it as a tool to accomplish distinct goals. An example of this could be, for instance, using the wearable to track steps to gain virtual awards from achieving a specific weekly step target. Lastly, the

'tutor' role of a wearable refers to "learning and being motivated by their longitudinal data in a reflective feedback loop" (Lyall & Robards, 2018).

Similarly to the triple role discussed above, Lehrer et al. (2021) identified four wearable use patters that result in different behavioral outcomes, noting that users can show different patterns depending on the use case. In the first use pattern, which is called following, users were highly motivated to change their health behavior, but did not know how to go about it, and thus relied on the wearable to guide them towards their goals. This use pattern can be compared to Lyall & Robards 'tutor' role of wearables. Furthermore, a 'toy' role can be seen in Lehrer et al.'s second use pattern. In the second pattern, called ignoring, users had low motivation to change behavior and mainly used the wearable out of interest or self-confirmation, ignoring any of the wearable's guidance. The third use pattern, combining, was characterized by high motivation to change behavior and strong reliance on the wearable's guidance at first, which later turned into routines, allowing users to be less dependent on the devices – using the wearable as a tool and a tutor. Lastly, in the fourth use pattern, self-leading, wearables were mainly seen as a tool to support already existing behavioral goals.

Based on Lyall & Robards' triple role of wearables and Lehrer et al.'s four use patterns it can be concluded that depending on the user's motivation and ability to change behavior, wearables can have varying roles in people's lives. Further, different behavioral outcomes may occur depending on the role of the technology.

2.5 Behavior change techniques in wearables

Wearable devices have been marketed as tools to change behavior and habits to a healthier direction. Kononova et al. (2019) state that wearables have the potential to promote these healthy behaviors through the integration of empirically tested behavior change techniques (BCT). A BCT is a "replicable and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior" (Michie et al., 2013). Behavioral interventions are often conveyed as complex systems with variable and short-term effects (Carey et al., 2018). The purpose of BCTs are to promote behavior change by intensifying the factors contributing to the change (Carey et al., 2018). Examples of commonly known BCTs include, for instance, goal-setting and social comparison (Lyons et al., 2014).

Consumer wearables contain a variety of BCTs normally utilized in clinical behavioral interventions (Lyons et al., 2014). Although there is no absolute evidence of best practices for behavioral interventions, prior research has provided general knowledge of the

predominant BCTs for successful change (Lyons et al., 2014). The Coventry, Aberdeen, and London-Refined (CALO-RE) taxonomy of BCTs is one of the most common frameworks for describing BCTs (Sullivan & Lachman, 2017). First published in 2011, the taxonomy contained 40 techniques, until Carey et al. later expanded the CALO-RE taxonomy in 2013 to 93 items. The taxonomy was utilized by Lyons et al. (2014) who studied 13 activity monitors to explore to what extent are BCTs included in the devices. They concluded that the devices included a range of 5-10 techniques, most of which were tools for self-monitoring, feedback, and goal-setting. Moreover, Mercer et al. (2016) reported an average number of 16.3 BCTs in a similar study. A more recent study by Lewis et al. (2020) stated an average of 27.7 BCTs in consumer wearables. Lewis et al. (2020) note that although several techniques were similar across the devices, some wearables are better for specific health interventions than others. Although coding dissimilarities may explain some of the variability in the results, it seems that the number of BCTs in wearables has increased over time.

Sullivan & Lachman (2017) note that it remains unknown whether BCTs included in fitness technology are sufficient for long-term behavior changes. Phillips et al. (2018) state that wearables lack many BCTs, e.g., social support and health coaching, which are used in other behavior change interventions. Therefore, they compare the efficacy of using wearables for sustained behavior changes to the efficacy of using a scale for weight loss: without additional support its power is rather limited.

3 Theoretical grounding

To better understand how wearable technology use may affect the health behavior of users, it is important to study what is meant by behavior change and discuss the theories that try to explain how behavior change takes place. The third chapter of the thesis focuses on the notion of behavior change support systems (BCSS) and the selected behavior change theories underlying the BCSSs, as well as other relevant theories for the research. The analytical framework for the thesis is introduced and discussed at the end of the chapter.

3.1 Wearable technology for health behavior change

Oinas-Kukkonen (2013) defines a behavior change support system (BCSS) as "a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception". In other words, BCSSs are persuasive systems designed with the intent to influence user behaviors.

Oinas-Kukkonen (2013) argues that the behavior and cognitive outcomes of behavior-changing technology can be distinguished into three different types: compliance change, behavior change, and attitude change. In a compliance change, the goal is to ensure that the user complies with the system's requests. In terms of wearable technology use, a compliance change occurs when the user follows the behaviors suggested or the goals set by the device, regardless of their motivation to do so. The key in achieving a compliance change is to provide clear triggers for the user to comply with. With a behavior change, the goal is to ensure a more enduring change compared to a compliance change. Lastly, with an attitude change, the goal is to change not only the behavior of users but their attitudes as well. This type of change is the most difficult to achieve. However, an attitude change can be seen as a requirement for a sustainable behavior change. (Oinas-Kukkonen, 2013)

Each type of the aforementioned changes can occur as one of three potential outcomes: formation, alteration, or reinforcement (Oinas-Kukkonen, 2013). Forming a new behavior or stopping an old one represents a forming outcome. Moreover, an altering outcome occurs when a person changes their response to an issue, for instance, by increasing their level of exercise. Finally, the reinforcement of current behaviors or attitudes represents a reinforcing outcome.

As a result, the behavior and cognitive outcomes of behavior changing technology can be outlined in a three-by-three design matrix (Table 1).

	Compliance change	**Behavior change**	**Attitude change**
Forming-Outcome	Forming an act of complying	Forming a behavior	Forming an attitude
Altering-Outcome	Altering an act of complying	Altering a behavior	Altering an attitude
Reinforcing-Outcome	Reinforcing an act of complying	Reinforcing a behavior	Reinforcing an attitude

Table 1. Outcome/change desing matrix (Oinas-Kukkonen., 2013).

Lehrer et al. (2021) note that wearables are in line with the concept of BCSSs as they are presented with built-in behavior change strategies to motivate users towards wanted behaviors. Wearable users may, for instance, form new behaviors such as weekly running sessions by using GPS tracking technology on the wearables to track their runs. Moreover, users may reverse unwanted behaviors, for instance, by utilizing sleep tracking to alter their bedtime habits. Finally, wearables may also reinforce behaviors, for instance, by offering data and statistics of previous activities to motivate the users to resume healthy behaviors.

Oinas-Kukkonen's concept of BCSS's is based on various behavior change theories, such as the Theory of Reasoned Action, the Self-Efficacy theory, and the Elaboration likelihood model (Oinas-Kukkonen, 2013). Furthermore, in prior research of wearable technology, several theoretical models of behavior change have been used to explain the interplay between behavior and wearable technology. The Theory of Planned Behavior (TPB), the Technology Acceptance Model (TAM), and Self-Determination theory (SDT) are among the most popular theoretical frameworks utilized in research focusing on the adoption of wearable technology. Nonetheless, the main focus of these studies has not been the actual behavioral outcomes of using wearables, but rather the motivational factors leading to the use of the technology. Overall, few studies have focused on health behavior change facilitated by wearables, let alone on the maintenance or abandonment of these behaviors. Self-efficacy theory, the Transtheoretical Model of Behavior Change, the Stage-based Model of Personal Informatics, and Self-leadership theory, are among the few theories

that have been applied in previous literature to research the behavioral outcomes of wearable use. In this section, the aforementioned theories, and their relevance to wearable technology facilitated health behavior change will be reviewed.

3.1.1 Self-efficacy theory

Self-efficacy refers to a person's belief in "his or her ability to perform a behavior and determines the confidence, effort, and perseverance with which he or she pursues a change in behavior" (Bandura, 1977). According to Bandura (1994), a person's belief in their self-efficacy determines how they feel, think, motivate themselves, and behave. Self-efficacy theory is among the most notable behavior change theories and it has been applied in various fields of research, such as cognitive psychology, education, management science, and IS (Rieder et al., 2021). Furthermore, a person's sense of self-efficacy can be strengthened through four sources: vicarious experiences, personal accomplishments, verbal persuasions, and emotional arousal (Bandura, 1994). As discussed earlier in the thesis, a person's level of self-efficacy can have a great impact on the experienced health effects of using wearable technology.

Rieder et al. (2021) utilized the self-efficacy theory to study how users' self-efficacy perceptions and subsequent changes in behavior are affected by wearable use. In their study, they focused on compliance change, the so called 'easiest' archetype of behavioral changes as shown in Oinas-Kukkonen's BCSS model in the previous subchapter. The study revealed that users' perceptions of self-efficacy are influenced by wearable use. Self-efficacy was strengthened through personal accomplishments: wearables provided information to the users, which helped them accomplish their goals. Moreover, elements or BCTs related to verbal persuasion, such as reminders and notifications given by the wearable, strengthened self-efficacy. Furthermore, users' self-efficacy was strengthened by vicarious experience, which refers to a person's belief that they can do a task because they either know or have seen another person being able to do it as well (Rieder et al., 2021). Lastly, a key insight from Rieder et al.'s study was that context plays a big role in self-efficacy beliefs. For example, negative external contexts, such as bad weather for running or long days at work, affected users' self-efficacy and consequent changes in behavior in negative ways.

3.1.2 Transtheoretical Model of Health Behavioral Change

The Transtheoretical Model of Health Behavior Change (TTM) is a behavior change theory that uses six stages to illustrate an individual's behavior change process (Prochaska & Velicer, 1997). Figure 1 below illustrates the stages of the model.

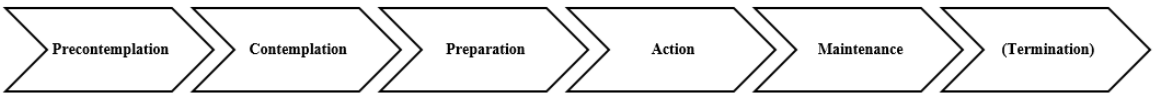

Figure 1. The Transtheoretical Model of Health Behavior Change (Prochaska & Velicer, 1997).

In the first stage of the TTM, precontemplation, people have no intentions to alter their behavior, which often results from not understanding the consequences of their behavior (Prochaska & Velicer, 1997). In terms of wearable technology use, people in this stage are ones who are either unaware of the technology or unaware of the potential health benefits of using the technology.

In the second stage, contemplation, people are aware of the pros of changing and have the intention to change their behavior in the foreseeable future, which is usually defined as the next six months (Prochaska & Velicer, 1997). For instance, people in this stage might be aware of the benefits of wearables and may have developed more interest towards the devices. However, people in the contemplation stage are also aware of the cons of changing, which may demotivate them from taking immediate action. For instance, people may be concerned about the accuracy of wearable devices, or they may fear that they are conceding their personal health data to the wearable providers.

The third stage, preparation, is the stage in which people have some sort of plan of action to change behavior in the immediate future, usually meaning within the next month (Prochaska & Velicer, 1997). Evidently, acquiring the wearable device and starting to record personal health data with it happens in the preparation stage.

The fourth stage, action, is where people have made changes in their habits and lifestyles within the past six months (Prochaska & Velicer, 1997). Such changes could be, for instance, using the wearable device and altering daily routines as a consequence.

In the fifth stage, maintenance, people continue the new behaviors and work to prevent relapse (Prochaska & Velicer, 1997). In terms of wearable use, relapse may be in the form of returning to old behaviors, such as ignoring the data provided by the wearable

and staying inactive, or even abandoning the wearable altogether. Relapse can also mean the return to one of the prior stages.

The sixth and final stage is called termination. In the termination stage people have no temptation to relapse or return to old unhealthy behaviors (Prochaska & Velicer, 1997). The termination stage is rarely reached and is therefore often not included in the TTM, especially in the area of health promotion. Prochaska & Velicer (1997) continue that termination is often not a realistic state in areas such as exercise and weight loss, which is why maintenance should be considered as the goal and final stage in these cases. In prior research, it has been stated that wearable technology has increased people's awareness of their habits, but not necessarily changed their behavior in the long-term. In terms of the TTM, wearable users seem to struggle moving from the stage of action to the stage of maintenance.

In the area of wearable technology research, the TTM has most notably been utilized by Kononova et al. (2019) in their study of older adults' use of wearable technology. They utilized the TTM to investigate the perceptions and behaviors of activity tracker users in different stages of the model, and to examine the factors contributing to the successful maintenance of positive health behaviors, or conversely, the factors leading to the failure to maintain the behavior. According to the research, wearable design greatly affects users' ability to maintain new healthy behaviors and drives long-term usage. For instance, behavior change techniques, such as reminders and motivational messages, were considered important. Moreover, they found that intrinsic motivation and social connectedness are among the most important determinants for reaching the maintenance stage, while data inaccuracy discourages long-term usage. However, Kononova et al. (2019) note that long-term usage is not a necessity for behavior change. They found that former wearable users have been able to obtain healthy behaviors after adopting a wearable device and then maintain the behaviors after discontinuance. This notion is similar to Lin & Windasari's findings discussed earlier in chapter 2.2.

3.1.3 Stage-based model of personal informatics

Another useful model to consider is the stage-based model of personal informatics systems, introduced by Li et al. (2010). They define personal informatics systems as systems that "help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge". Although the stage-based model of personal informatics was originally derived from the TTM, the model is not a behavioral model per se, as its purpose

is not to explain how people go about changing behavior. Instead, its purpose is to explain how people collect, reflect and act on personal information about the self and their own behavior (Li et al., 2010). Therefore, the model is suitable for researching the topic of this thesis.

The five stages of the stage-based model of personal informatics systems are preparation, collection, integration, reflection, and action (Li et al., 2010). In addition to there being barriers related to each individual stage, the barriers cascade to later stages, i.e., problems encountered in previous stages may affect the later stages. Moreover, the stages are iterative, meaning that as people advance through the stages they may incorporate new tools, processes, or data.

Figure 2. Stage-based model of personal informatics systems (Li et al., 2010).

The stages can be user-driven, system-driven, or a combination of the two (Li et al., 2010). In the case of a user-driven (system-driven) stage, the user (system) is responsible for the activities in the stage. For self-tracking with wearable technology, the first stage (i.e., preparation) is both system-driven and user-driven. It is determined by the wearable design what information can be recorded and how. The user may, however, choose the wearable device they want to acquire, as well as select what parts of the recorded data they wish to pay attention to. Moreover, the user may have control over what or how data is to be collected by the wearable, presuming the wearable has the ability to collect that data. For instance, if the user utilizes the wearable to collect data from a physical activity, they may decide what they wish to track (e.g., distance, heart rate) and how (e.g., with GPS, GLONASS, pedometer). The next two stages (i.e., collection and integration) are system-driven. The data is automatically and objectively collected by the wearable device, given that some activities are automatically recorded by the wearable, whereas some activities might require the user to start the recording on the device. Then, the collected data is prepared, combined, and transformed by the technology for the user to reflect on. In the fourth stage (i.e., reflection) the user reflects on the collected information (Li et al., 2010). This stage is mostly system-driven but may be user-driven to a limited extent. The wearable technology usually provides the user with visualizations and other reporting tools to ease the

interpretation of the data. The visualizations may be accessed directly from the wearable device or by pairing the device to a mobile app or laptop, for example. The user may also reflect on the data without such tools provided by the technology. In the final stage (i.e., action), the user decides what to do with the new knowledge and understanding of themselves (Li et al., 2010). In other words, the user decides if they want to change their behavior and how to go about it. The user may, for instance, adjust their exercise routine or sleep habits based on the insights they made from the data. The wearable may also alert the user to take action, for instance, by suggesting them to move after a long period of sitting or to recover after a heavy activity.

Liang & Ploderer (2016) utilized the stage-based model in their study where they investigated the impact of wearable use on sleep improvement. The study included 12 participants who acquired a wrist-worn wearable device (Fitbit) to be worn for 1.5 to 6 months to record data on their activity and sleep. They utilized semi-structured interviews to study the effects and potentials barriers of using wearable technology to improve sleep. The main finding of their study was that wearable users struggle in moving from the stage of reflection to the stage of action. The use of wearable tracking increased the users' awareness of their sleep quality and sleeping habits but did not help them improve their sleep.

Furthermore, they identified three main barriers for improving sleep with wearable technology. First, people may not know what normal sleep is. The data provided by a wearable is of little use for the user if they do not understand what the information actually means. A key problem in this is the lack of reference points (Liang & Ploderer, 2016). For instance, showing a graph of restlessness during sleep provides no value to the users if they do not know what a "normal" amount of restlessness would be. Second, people may not understand the reason behind sleep problems. For instance, the wearable might show data about the times that a user woke up during the night but does not tell any further explanations for why they woke up in the first place. Moreover, users may have difficulty to understand connections from lifestyle factors to their sleep problems. For example, the user may not understand that heavy activity or eating a heavy meal just before bedtime may cause their resting heart rate to being high during the night. Third, and most importantly, they found that users do not know how to act on the data to change their behavior. Linking this to the stage-based model of personal informatics, Liang & Ploderer (2016) argue that wearable users struggle in moving from the reflection stage to the action stage. Ravichandran et al. (2017) had similar findings in their study of improving sleep with self-tracking. They noted

that users were frustrated if wearable feedback emphasized the aspects of sleep that they do not know how to control, such as time spent in different sleep stages, over aspects that are easier to control. Clearly, personalized recommendations and feedback on which actions to take seem to be important in guiding wearable users to move from awareness to action.

3.1.4 Lived informatics model of personal informatics

Epstein et al. (2015) developed a revised model of Li et al.'s stage-based model of personal informatics systems based on their findings of how people use self-tracking tools. They note that in addition to reaching behavior change goals, which is emphasized in the original five-stage model, people use self-tracking tools to instrument an activity or simply out of curiosity – a similar notion to Lyall & Robards' (2018) 'toy' role of wearables discussed earlier in the thesis. Moreover, they found that the reasons for a user to switch tracking tools are more varied than in Li et al.'s model, and that the original model does not adequately explain the reasons why people stop tracking.

In the lived informatics model, the first stage, preparation, is divided into two: deciding and selecting. The deciding stage is closely linked to the precontemplation and contemplation stages of the TTM, and simply refers to the decision to track personal data (Epstein et al., 2015). The second stage, selecting, refers to the selection of a specific tool to track the data with (Epstein et al., 2015). As opposed to Li et al.'s model, in which collection, integration, reflection and action are separated into individual stages, Epstein et al. (2015) argue that these activities are mostly performed simultaneously. As a result, they define tracking and acting as the third step of the lived informatics model, which comprises of collecting, integrating, and reflecting. This step is followed by the stage of lapsing (Epstein et al., 2015). They state that the lapsing stage can either be short-term, such as forgetting to bring a tracking device to a trip, or long-term lapsing, such as stopping tracking for several months. In case of a short-term lapse, the stage is usually followed by resuming the tracking (Epstein et al., 2015).

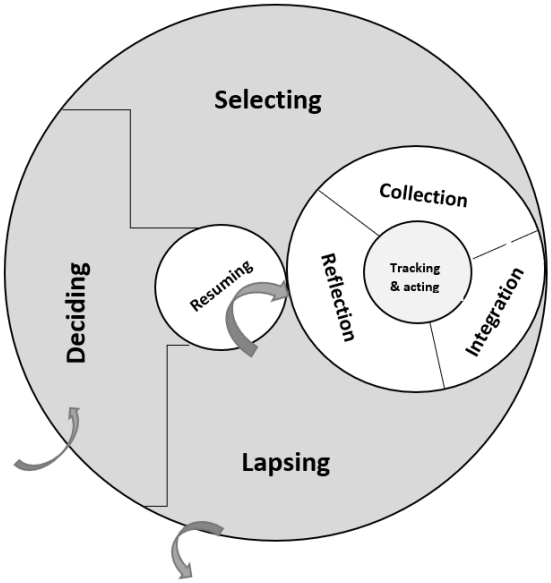

Figure 3. Lived informatics model of personal informatics (Epstein et al., 2015).

3.2 Analytical framework

The theory presented and used in this thesis is based on Oinas-Kukkonen's (2013) concept of behavior change support systems (BCSS), the underlying behavior change theories behind BCSSs, and other relevant theoretical models that conceptualize how the use of personal informatics affects changes in health behavior. The analytical framework for this research has been developed by the author of this thesis by combining the relevant issues that were discussed in the literature review. More specifically, the framework was created by adapting Li et al.'s (2010) stage-based model of personal informatics systems with the main issues that contribute to the perceived health effects of using wearable technology. In the analytical framework, the ovals on the top row depict the process or the conceptualized steps that outline how the use of wearable technology affects changes in health and wellbeing. Moreover, the bottom row links the process above to the stages in Li et al.'s Stage-based model of personal informatics systems, which was discussed in detail in the previous chapter of the thesis.

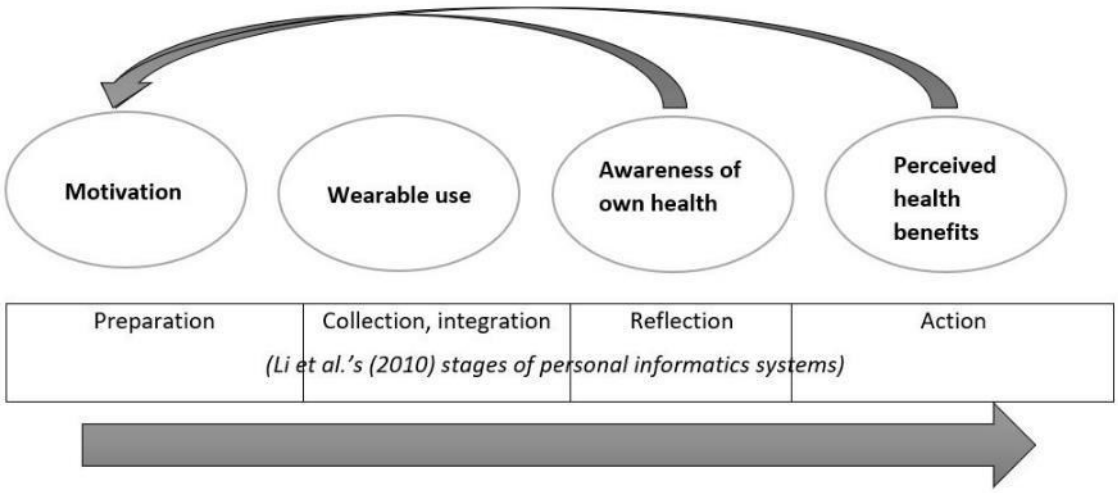

Figure 4.Analytical framework for the thesis.

First, the analytical framework exhibits that wearable technology use is affected by the motivation of the user, which can be intrinsic or extrinsic. People that are intrinsically motivated use wearables for fun, to accomplish something or to learn something new (Schaffarczyk & Ilhan, 2019). Extrinsically motivated people, on the other hand, use the devices to avoid taking too little exercise, to feel rewarded, or to get approval by others (Schaffarczyk & Ilhan, 2019; Attig & Franke, 2019). Motivation is featured across behavior change theories, even if the motivational constructs differ among them (Johnson et al., 2016). Moreover, it is clearly indicated in previous literature that improvements in wellbeing are impacted by the user's motivation to change behavior (Lyall & Robards, 2018; Lehrer et al., 2021).

The intrinsically or extrinsically motivated person with high or low motivation to change behavior uses wearable technology to collect personal health data about themselves. As the model hypothesizes, this use of wearable technology leads to increased awareness of the user's own health and habits. Ideally, the increased health awareness leads to changes in wellbeing in the form of perceived health benefits. These benefits include health improvement, a more active lifestyle, benefits in exercise workout, and improvements in perceived general health (Lunney et al., 2016). Moreover, the perceived health benefits and improvements in health awareness can further motivate the user to use the wearable technology, as depicted in the model.

4 Research methodology

In any research, it is important to assess the research problem and research question before selecting a particular research approach (Hakala, 2017). The best method for any study depends on the purpose of the research. As Silverman (2015) says: "different questions require different methods". The main research question of this thesis is "*How do consumer health wearables affect the health and wellbeing of users?"*. The purpose of the study is to explore how people use wearable technology and what are the perceived health benefits of collecting personal health data with wearable technology. Moreover, the aim of the research is to examine if the reflection of the collected personal data increases the awareness of users' habits and if that eventually results in changes in health behavior. As a result, the sub-question of the thesis is "*Does the use of wearables increase the awareness of users' current health behavior, and if so, does this facilitate health behavior change?"*.

Research methods are generally divided into two: quantitative and qualitative research. Quantitative research refers to the collection and analysis of numeric data to support or refute hypotheses about a particular problem (Williams, 2007). It seeks explanations and correlations between variables by generating data that allow numerical and statistical analysis (Silverman, 2015). Quantitative research methods include surveys, experiments, observations, content analysis, and analysis of previously collected data (Silverman, 2015).

Qualitative research, on the other hand, involves verbal descriptions of real-life situations (Silverman, 2015). Compared to quantitative research, qualitative methods are better for exploring and understanding the complexity of a phenomenon (Williams, 2007). Qualitative data can be collected, for instance, through interviews, focus groups, or ethnography (Silverman, 2015).

The chosen method for primary research for this thesis is qualitative research. Sargeant (2012) states that qualitative methods are best for research questions that start with "how" or "why", whereas quantitative methods are better suited for "what" questions. According to Fossey et al. (2002), qualitative research methodologies are appropriate for understanding subjective experiences of health and disease. As the main focus of the research is to understand the perceived health benefits of using wearable technology through the research question "*How do consumer health wearables affect the health and wellbeing of users?"*, the qualitative research method is suitable for this thesis. Moreover, qualitative research is often used in situations where there is a lack of theory or existing theories fail to adequately explain a phenomenon (Merriam, 2002). For this research, there were no existing theories

that could have been used to test hypotheses with quantitative methods, and that would have adequately answered the research questions formulated at the beginning of the thesis. According to Silverman (2015), qualitative research methods can provide a deeper understanding of social phenomena than quantitative methods.

There exist several methods for qualitative research. Williams (2007) distinguishes among the following five: case study, ethnography, grounded theory, content analysis, and phenomenological study. A case study is an intensive analysis of a phenomenon or activity, such as an event, a program, an individual, or a group (Williams, 2007; Merriam, 2002). An ethnography study differs from a case study in that it studies a larger group that shares a common culture (Williams, 2007). Moreover, grounded theory refers to a qualitative method in which the goal is to develop a theory inductively from the data, which is grounded in the views of the study participants (Merriam, 2002; Williams, 2007). A content analysis can be defined as a detailed examination or analysis of a specific body of material, such as books, newspapers or movies, to identify themes, patterns or biases (Williams, 2007). Finally, a phenomenological study focuses on understanding an experience from the view of the participants (Williams, 2007). Whereas ethnography focuses on culture, in phenomenology the focus is on the structure or essence of an experience (Merriam, 2002).

The chosen qualitative method for this thesis is the phenomenological study. The method is appropriate for the thesis because the purpose of the research is to understand the experience of using wearable technology and how it affects the wellbeing of the users. As was discussed in the literature review, wearables can play different roles for different people, or even different roles for the same person depending on the scenario. Moreover, the perceived health benefits of wearable use can be very subjective. Therefore, understanding the experience from the users' point of view through phenomenology is appropriate for this research.

The biggest challenge in a phenomenological study is that the researcher often has a connection, experience or stake in the situation. However, to understand the experience, the researcher must put aside all prejudgments, attitudes, or personal beliefs about the phenomenon. (Merriam, 2002)

4.1 Data collection

The three major sources for data collection in qualitative research include interviews, observations, and documents. Moreover, interviews range from structured, where the questions and their order are predetermined, to unstructured, where there are no

predetermined questions about a specific topic area. Most interviews are semi-structured – somewhere between the two extremities. In semi-structured interviews, specific information is desired from all interviewees, which is why the majority of the interview is guided by a predetermined list of questions. However, the exact wording or the order of the questions are not determined ahead of time. (Merriam, 2002).

The data collection for the thesis was conducted via semi-structured interviews. The method was chosen because the research has clear themes and questions that need answers. At the same time, the semi-structured interviews allow for enough flexibility to adjust the questions to the behaviors of the interviewees. An advantage of semi-structured interviews is that the method allows for asking follow-up questions in addition to the predetermined ones, which helps the researcher to go deeper into the most important subjects in the interview (Silverman, 2015).

All interviews were conducted in Finnish. Five interviews were held face to face and seven were conducted via Microsoft Teams. The interviews were held in January and February of 2023. The interviews were audio recorded to help the researcher return to the material later to revise the interviews. The recording of the interviews also allowed for transcribing the material to conduct proper analysis. The interview questions can be found in Appendix A of the thesis.

4.1.1 Sample selection, size, and diversity

One of the most important steps in designing a qualitative study is to identify appropriate participants for the study (Sargeant, 2012). Instead of random sampling, which is often used in quantitative studies to ensure generalizability of results, qualitative research uses purposeful subject selection to ensure that the selected study participants are those who can best enhance the understanding of the phenomenon by providing informative answers to the research questions (Sargeant, 2012). For the purpose of this research, the ideal sample would consist of people with diverse backgrounds and different use purposes for wearable technology. As discussed earlier, in this thesis health and wellbeing will be examined from a relatively broad perspective, including not only physical activity but also subjective wellbeing, quality of life, and sleep among others. Therefore, it is beneficial for the study that the interviewees are not limited to those who use wearable technology only to track exercise but include those who prioritize tracking sleep or steps, for instance.

In this thesis the sampling method used was purposive sampling, which is a non-probability sampling technique in which the interviewees are selected because they meet

certain criteria or have characteristics that are relevant to the research question (Nikolopoulou, 2022). The purposive sampling method relies on the researcher's judgment for selecting the interviewees that are able to provide the most suitable information to reach the objectives of the study.

The interview sample for this thesis consisted of 12 wearable health technology users with diverse backgrounds. All of the interviewees were found through personal networks, except for two interviewees who were recommended by other interviewees. The main criteria for selecting the research participants were twofold. First, the person had to use some type of wearable health technology to track various health metrics. Second, the person had to be a long-term user of the technology, with at least one year of use.

The majority of the users tracked various activities with the devices, most notably daily activity, steps, sleep, and specific exercise activities such as running or cross-country skiing. The interviewees were all considered long-time users of wearables, with everything from one year to more than ten years of use. Moreover, many of the interviewees currently used multiple wearable devices or had previously used other wearables in addition to the currently used ones. Table 2 provides an overview of the interviewees.

Interviewee	Currently used wearable(s)	Years of use	Main use or metrics monitored
1	Oura ring	3	Activity, sleep, recovery
2	Oura ring, Garmin Venu 2	10	Activity, sleep, workouts, recovery
3	Garmin Vivofit	1	Activity
4	Garmin Venu 2 S	2	Activity, workouts, recovery
5	Polar Unite	3	Activity, workouts
6	Oura ring, Apple Watch	5	Activity, sleep, workouts, recovery
7	Oura ring, Suunto Spartan	5	Activity, sleep, workouts, recovery
8	Garmin Venu 2	5	Activity, workouts
9	Suunto 9 Pro	5	Activity, workouts
10	Apple Watch	4	Activity, workouts
11	Apple Watch	4	Activity, sleep, workouts
12	Oura ring, Suunto 9	4	Activity, sleep, workouts, recovery

Table 2. Summary of the interview participants.

4.2 Data analysis

The interviews were transcribed from the audio recordings for easier analysis. Thematic analysis was utilized to code the data into specific themes that fully describe the interviewee's lived experiences. The thematic approach was already considered when designing the interview questions, mainly because the analytical framework built for this thesis includes specific themes or steps that try to conceptualize how the use of wearable technology affects the health behavior of users. Moreover, in semi-structured interviews it is always likely that some themes may arise that were not considered by the researcher in advance, hence enlarging the scope of themes.

After the interviews were transcribed, the transcriptions were read multiple times by the researcher to identify common themes. The themes were selected based on the ones that were categorized before the interviews as well as the ones that arose during the interviews by the interviewees themselves. The main research question and objectives were kept in mind during the whole process to identify which themes are important for answering the research question of the thesis. The data were then categorized under the specific themes for further analysis.

4.3 Research ethics

Research ethics is an important aspect in all research. The research ethics and integrity guidelines at Aalto University were studied with great detail before conducting the interviews. For this research, all interviewees participated in the study out of voluntary reasons and none of them were compensated in any way for taking part in the research. The interviewees were all handled anonymously and any type of personal data that could reveal the interviewee's identity, was left out. Before each interview, the interviewee was asked for consent for recording the interview. The researcher informed the interviewees that the recordings would only be used for the purpose of transcribing the conversations for easier analysis, and the recordings would be deleted immediately when they were not needed anymore for that purpose.

5 Findings

In this section, the findings from the semi-structured interviews are discussed. The findings are discussed in themes, which were based on the questions of the interview as well as other topics that were brought up by the interviewees. The analytical framework, which was introduced earlier in this thesis, guided the analysis of the interview data. Next, the findings are presented accordingly.

5.1 Motivation for using wearable technology

Although the motivational factors for adopting wearable technology may differ from person to person, all of the users stated general curiosity as one of the main factors for the adoption of the device. Multiple interviewees stated that they were initially interested in trying the technology in order to learn how well the device detects their daily activity, to see what parameters the devices track, and how well the technology works. All interviewees were thus generally interested in increasing their awareness and knowledge about their current habits and health, which was also hypothesized in the analytical framework of the thesis. Many of the interviewees had used wearable technology for more than five years, indicating that they could be seen as early adopters of the technology. Therefore, the finding of general curiosity as a main motivator can be considered expected.

> *"Maybe the curiosity about how the watch detects my daily activity, and how much I actually have that active time during the day. Sleep I only track out of interest, to see how well it says that I slept."*
>
> Interviewee 5

> *"At first, I was interested to see the amount of sleep and activity. Most of my family also track, so I wanted to see my own numbers."*
>
> Interviewee 1

The most common method for measuring daily activity was through step counts. Some interviewees also stated that they follow other metrics, such as calories burned, or time spent sedentary to evaluate their level of activity. A few interviewees stated that they followed daily activity through a more complicated measure that utilized multiple metrics to

form a number between 0 – 100 to indicate how active the user has been. However, the majority of the interviewees stated daily steps as the main metric for daily activity.

According to research, roughly 10 000 steps per day is generally a good long-term goal for achieving notable health benefits (Duodecim, 2021). This recommendation was widely known by the interviewees, as they stated that they wanted to track daily steps to get an idea how close they get to that target on an ordinary day in their life.

> *"Maybe it was like, to know with what different things I can reach that goal. Like, how does it go on a normal day, when I walk to school and go to my hobbies. To see how those affect the step count, and what is my activity level."*
>
> Interviewee 3

Regarding the motivational factors for using the technology, a number of interviewees stated that they were generally interested in data, numbers, and statistics. Some interviewees described themselves as 'somewhat of a nerd' and stated that as a motivation for collecting health data. In general, the interviewees wanted to record health data and then compare that to their own subjective feelings.

> *"I think sleep data is really fascinating just in general. It's really fascinating to see what the device claims about my sleep behavior, and to compare that with my own opinions about it."*
>
> Interviewee 2

> *"The main reason why I wanted this was to see how my life looks like objectively, through someone else's lens. To view my behavior through data from that device."*
>
> Interviewee 4

5.2 Motivation to change behavior with the use of wearable health technology

Out of the twelve interviewees, four expressed low motivation and intention to change their health behavior through the use of wearable health technology. Two of them explicitly stated that they were already living a very healthy and active lifestyle, and that they therefore mainly wanted to use the technology out of curiosity to see how well the technology works

in their opinion. They were interested to see how their lifestyle appeared in terms of data but did not plan to act on that information. The other two noted that the main purpose for their wearable use was to maintain an activity log to see how active they are at certain periods of time. Moreover, they were more interested in monitoring their current status than actually changing their habits in any way.

Most of the interviewees, nonetheless, were highly or moderately motivated to change their health behavior in some way, and for them, that was one of the main sources of motivation to start using the technology. For some of the interviewees, the motivation was higher when first adopting the device, whereas others stated that they were still highly motivated to change their behaviors to live healthier lives.

> *"Well yeah, there was [motivation to change health behavior]. Maybe more at the beginning…that I wanted to reach the daily goal. But the more I used it, the more that motivation decreased. So, I didn't make any effort anymore to reach that 100%."*
>
> Interviewee 5

> *"The main thing is that I want to progress in certain areas of life. For instance, when talking about sleep and exercise, or health in general, a good way to do that is monitoring things on a daily basis – to see where we're going and how my daily exercise and sleep work out. That's maybe the reason why I jumped onboard with this. And then also just general interest about health, to see some data about that, but mostly it was about developing myself and moving forward in life."*
>
> Interviewee 6

Another aspect that came up in the interviews was that many of the users had some specific goal or target regarding their health behavior, and they utilized wearable health technology to help them reach those goals. For some, the goal was more specific, while for others it was more generic.

> *"I use it to support my training as I am preparing for a half marathon."*
>
> Interviewee 2

> *"So that my lifestyle change would kick-off and that I could monitor how it is going."*
>
> Interviewee 8

"To maintain my level of fitness and to measure the development of my training performance."

Interviewee 7

5.3 Analyzing the wearable data

The health data recorded by the wearable technology can be analyzed either directly from the device itself or by first synchronizing the device with a mobile phone and then investigating the data in a mobile app. Of course, the device must have some sort of visual interface for the data to be visible from the device itself. For instance, data recorded with a smart ring must therefore always be synced with an app first.

Most users who had the opportunity to view the data directly from the device, used it as the main way to look at the data. However, most stated that they also synced the data with a mobile app and used that to analyze the data. For some interviewees, the device was connected with their phone at all times, making it easy to analyze the data either from the device or from the app. Moreover, many interviewees noted that the use of an app allowed for more detailed analysis as not all health data was accessible straight from the device itself. Some also stated that it was more pleasant for them to reflect on the data from the app as opposed to the small screen on the wearable. A common trait with many users was that they used the wearable display for taking quick looks at the data, and then utilized the apps for more extensive reflection.

"I used an app. The watch wasn't so high-tech that I could've viewed all of the sleep metrics from it – it required the use of the app. And it was also a lot more pleasant for me to view the data from the app. I maybe viewed my daily activity level directly from the watch as well as some specs right after a workout, but otherwise I used the app."

Interviewee 5

Most interviewees who reflected or viewed the data directly from the device used it to monitor their activity in the middle of the day or to reflect on their exercise data right after the workout. The ones who used the wearable to record specific exercise activities usually reflected on the data immediately after the workout. One interviewee noted that it is easier to make conclusions from the data right after the workout because at that point she still has

a fresh sense of how it actually felt, making it easy to compare the data to her own subjective feelings. Similarly, many interviewees stated that they reflected on the data right after a workout to get an idea of how demanding the workout actually was on their body. Most of the devices used by the interviewees calculated some sort of intensity level or training effect to provide the user with an easy to understand metric for the intensity of the exercise. Many also reflected on the average and maximum heart rates, as well as distance traveled, to understand the effort of the workout. Those who stated that they viewed the data during a workout, mainly did so for running activities. According to them, the wearable data helped them exercise better as they were able to monitor the time, distance, and heart rates as they were running – making it easy to decide whether they are running too fast or too far, for example.

> *"When I'm running, I want to know exactly for how many kilometers and for how many minutes I've been running, and what the heart rate says…like, am I about to collapse right now or in a hundred meters."*
>
> Interviewee 2

5.3.1 Short term versus long term analysis of wearable health data

The interviewees mostly reflected on very short-term wearable health data. As was discussed earlier, most users reflected on the data either during or immediately after a workout, as well as reflected on daily activity data in the middle of the day. Most interviewees noted that they reflected on the wearable data usually at the beginning – or at the end – of a day, depending on what data they were collecting with the device. Those who recorded sleep data with the wearable, usually viewed their sleep data first thing in the morning. For most, it had become such an integrated part of their morning routine that they practically never failed to check the sleep data within the first hours after waking up. Moreover, for them it felt logical to reflect on the data right away because then they could compare the data to their own feelings, making it easier to interpret the numbers and conclude whether they agreed with the data. One interviewee said that he analyzed the sleep data first thing in the morning and made a type of action plan based on it. For instance, if the data indicated that he had slept worse than normally, he would reflect on the events of the previous day and recognize the actions that could have negatively affected his sleep quality. He would then develop a list of things that he could do that day to make sure his sleep scores were better the next morning.

Moreover, those who recorded and reflected on the daily activity data viewed their data usually during the day or at least in the evening before going to bed. Only two interviewees stated that they did not monitor the data on a daily level or during the day, but instead a few times a week to understand how their week is going – instead of how their day is going.

"First thing in the morning when I wake up, I sync my Oura ring and check how my night went. And then in the evening before I go to bed, I check my daily activity as well."

Interviewee 1

"It's like, always checking my sleep in the morning – what happened there, how I've slept, what type of sleep I've got. Then during the day sometimes checking the daily activity to see where we're at. In the evening also just a quick browsing to check how was my day in terms of activity and training."

Interviewee 6

For the interviewees, the key in reflecting on very short-term health data was that they could make quick decisions to change their health behavior. For example, many interviewees stated that they reflected on the daily activity or step data in the middle of the day in order to decide whether they should be more active towards the end of the day or if they had been moving a lot already. Thus, wearable technology functioned as a monitoring system that helped the users make better decisions during the day. Similarly, the interviewees who recorded sleep data stated that they wanted to reflect on the data right after waking up so that if their sleep quality was poor, they would have the whole day to do things that would help them get better results the following night. Many interviewees also stated that they often reflected on the past week's activity data and made plans for the rest of the week based on that. One interviewee said that he liked to reflect on the wearable health data multiple times a week because it would give him positive reinforcement and a great feeling if he noticed that he is currently having a very active week. On the other hand, if he was having a lazier week, he would still have time to correct that later during the week.

"It's sort of a training log for me. So I may look from there whether I've had an active week already or if I should be more active towards the end of the week."

Interviewee 10

Although the interviewees in general spent lots of time analyzing short-term wearable health data, long-term trends were mostly overlooked by them. Most of the interviewees said that they sometimes looked at the longer trends, such as their average daily activity over a two-month period, but that it was not done systematically or regularly at all. For the long-term data, they mainly relied on the visualizations or easy-to-read summaries that were automatically provided by the wearable or the app. Some said that they sometimes noticed interesting things from the long-term trends and summaries, but that those did not affect their behavior in any way. Those insights were regarded more as additional information that was simply nice to know. For example, one interviewee said that he enjoyed reflecting on the longer-term data because he could learn new things, such as, at what time of the day or on what day of the week is he generally being the most active. Nonetheless, he never acted on that data in any way, but rather tried to reason why, for example, the data stated that he was usually the most active at 5 PM on Sundays.

> *"I rarely look at those longer trends, but maybe every few months I might take a look just out of curiosity. For example, to see how the summer months have been, as I've had a lot more free time, as opposed to how the fall or winter months look when it's more about working and having the normal routines. So just out of curiosity I might have had a look at how those two differ. However, it's not that systematic at all. But the daily checking really is."*
>
> Interviewee 6

Although most interviewees focused on viewing short-term data, some users were also notably interested in analyzing long-term wearable health data. Two interviewees stated that they followed very closely the weekly, monthly, and yearly statistics of the various activities they were recording with the wearable technology. For instance, one interviewee was a very passionate cross-country skier who had monthly goals for the sport. Therefore, he wanted to follow the weekly and monthly trends as well as yearly totals to understand how well his training was progressing. Moreover, he recorded sleep and recovery data with the wearable, and wanted to follow the longer trends in order to understand if his training and recovery were balanced. He stated that from the longer trends he could easily notice if he was training too much and needed to rest. Similarly, another interviewee liked analyzing the longer trends in the data because he could get quick insights from which to draw conclusions if he needed to change his health behavior in some ways.

"This is great, that you can see this two-month trend from Oura – how the readiness score, sleep quality, and activity are progressing. So, I do check this. For example, right now my activity level has been increasing for three weeks, whereas my readiness and sleep quality are decreasing. So, from that you can easily calculate what should be done."

Interviewee 7

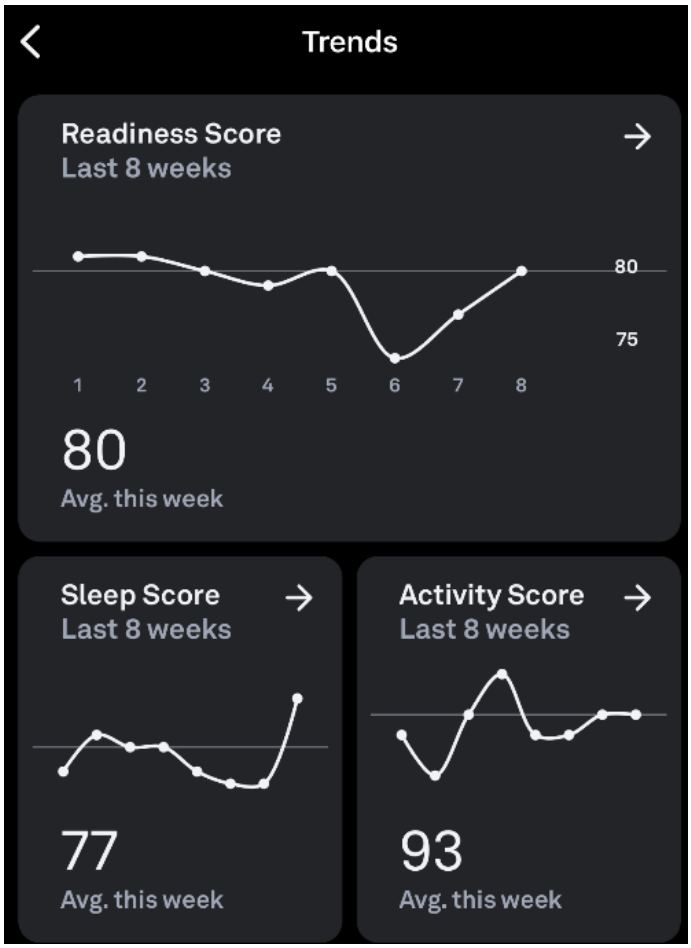

Figure 5. Screenshot from the Oura app: Examples of the health trends.

Many of the interviewees said that they had a feeling that they did not analyze the wearable health data as much as they could have been analyzing. Some felt that they followed a few key metrics from the data but noted that there would have been a lot more data that they did not currently analyze in any way. For instance, one interviewee stated that she often reviewed her nightly resting heart-rate data out of curiosity, but never actually thought why the data varied or what things or patters she should have been paying attention

to. She was aware that generally speaking, lower heart-rate values were better, but had no idea how to make sense of the curves and trends in the data that were presented in the app. Similarly, another interviewee was interested in analyzing long-term wearable health data, but she was unsure of how to go about it and what types of conclusions she should be drawing from the data. One interviewee noted that the technology enabled for adding tags to the data, such as 'alcohol' or 'golf', which would make it easier to analyze the data later on. For example, he could notice that every time a particular week was having many 'alcohol' related tags, he was having a significant drop in sleep quality. However, he said he rarely used that function even though he knew it would make it easier to make conclusions from the data.

5.4 The awareness of current health behavior

The interviewees were asked if they felt that the use of wearable health technology had increased the awareness of their current health and behavior in some ways. In general, all interviewees stated that the use of the wearable had increased their self-awareness, at least to some extent. For many interviewees, reflecting on the wearable health data brought visibility to their daily habits by quantifying their lives, which increased their understanding of their health. As was hypothesized in the analytical framework, the increased awareness acted as a motivation to continue the use of wearable technology. For many, the data mainly supported the previous knowledge the users had about their health, but also brought up some new information. Only two interviewees believed that the use of the technology had very low impact on the awareness of their health and behavior, and that the insights they got from the data were more of 'nice to know' than something that would in fact be useful for improving their health behavior.

> *"I'm sure you could figure out the same things without the device, but it sort of tells you that hey, have you noticed this already?"*
>
> Interviewee 12

5.4.1 Awareness of one's own level of activity

Some of the interviewees felt that the use of wearable technology mainly supported their subjective feelings and reinforced their current beliefs rather than brought up new knowledge about their health. The wearable health data had a very modest positive effect on increasing self-awareness especially for those interviewees who were already very active and who

engaged in regular exercise activities. One interviewee noted that he could already tell when he was being active, and when he was not, and that the wearable data mainly supported that knowledge. Nonetheless, the use of wearable technology acted as a concrete reminder, guiding his thinking to embracing healthier habits. For example, if he had spent the whole day sitting at home, he would already know that without the technology, but when the wearable would display that he had recorded only a few hundred steps during the day, he would pay more attention to the fact that he has been very passive. Another interviewee said that although she felt like the use of the technology had not increased her awareness much, she would sometimes be positively surprised that she would record many steps with the wearable even when she felt she had not had an active day at all. Similarly, one interviewee said that the use of the wearable increased his understanding in that many daily errands could be comparable to some exercise activities.

For many interviewees, the key was that the use of wearable technology provided them with a concrete and objective view of their health behavior, which increased their awareness and understanding of it. Only one interviewee said that the wearable health data was often contradicting her own subjective feelings in a negative way. A few other interviewees agreed that the use of wearable technology increased their awareness in a negative way, as it displayed that they were not in the best shape or had not been very active. However, they noted that the data was in line with their own feelings – they knew that they were not living the healthiest lifestyle and the data supported that perception. One interviewee stated that although it was not always enjoyable to look at the activity data, it increased his understanding of his current health status by providing exact figures of how active or passive he in fact was.

5.4.2 Awareness of one's own sleep quality and recovery

The interviewees who recorded sleep data reported that the use of the wearable technology increased their self-awareness a lot. For many users, the use of the technology not only increased visibility to how much they were sleeping, but also to how well they slept and how well they were recovering from their daily activities. These were measured, for example, by the amount of sleep in different sleep stages, e.g. REM sleep or deep sleep, by the average and minimum heart rate during the night, and by the amount of movement while sleeping. One of the main reasons why sleep tracking seemed to increase self-awareness more than activity tracking, was that sleep is relatively hard to evaluate subjectively. Some of the interviewees stated that, for the most part, they could evaluate how well and for how long

they slept, but the wearable data would give more detail to what their sleep quality consisted of.

> *"The more data it collects, and specifically the type of data that you can't observe yourself, the more it increases awareness and understanding."*
>
> Interviewee 3

> *"Almost always it supports my own feeling. But when you look at this data, it gives you the explanation to why you're feeling the way you're feeling. You can see all these parameters from here, and you can understand why you are feeling that way. The readiness or sleep quality score you could probably guess, but the reasons for those scores are then explained here by the data. And that allows you to fix the right things."*
>
> Interviewee 7

Many interviewees stated that sleep tracking increased their awareness a lot because with the help of the tracking they begun to understand which things have an effect on a person's sleep quality. Multiple interviewees noted that even small alcohol consumption would immediately be reflected in their sleep quality and recovery data. Another interviewee stated that by reflecting on the sleep data, he understood that intense or stressful periods at work would always result in a decrease in sleep quality and overall energy levels.

> *"In my opinion it definitely has increased my self-awareness, the Oura ring especially. You're able to see...well, the effect of alcohol of course, but for example a candy bag – the same exact effect. So, your body is tired, and you sleep really bad. So it has clearly taught things like these."*
>
> Interviewee 12

Another metric that was considered very insightful was body temperature. The Oura smart ring measures the user's body temperature every night, indicating how well the user is recovering, how prepared they are for the day, or whether they might be coming down with an illness (Oura, 2022). For many interviewees, the body temperature metric increased their awareness about all the aforementioned things.

"The body temperature has been very accurate, and I've been able to anticipate whether I've caught a flu or even covid, which was quite interesting."

Interviewee 2

"It has been a very big added value that it shows you the body temperature during the night. There was a time, for instance, when I had a significant fever, but I didn't wake up to it. If it wasn't for the ring, I wouldn't have even known that at all. I just wondered that I had slept quite poorly and saw some weird dreams, but when I checked the data, I realized that, hey, I've actually had a fever."

Interviewee 12

Lastly, many interviewees stated that they liked monitoring the more complicated, ready-made metrics about recovery with their wearables. For example, the Oura Readiness Score and Garmin Body Battery both indicate an overall rating of the user's recovery on a scale from 0 to 100, taking into account various parameters such as latest sleep data and the previous day's activity. The interviewees stated that those metrics increased their consciousness and understanding of their overall recovery state. Moreover, those metrics were considered accurate and easily digestible representations of data.

5.5 The perceived health benefits of wearable technology use

Ten out of twelve interviewees agreed that the use of wearable technology has had positive effects on their health behavior and health in general. According to a number of interviewees, simply having the wearable device visible on their wrist or finger motivated them to be more active because it acted as a constant reminder that the wearable is collecting health data throughout the day. At the same time, some users noted that although they had changed their health behavior to the better since starting the use of wearable technology, it was influenced by a number of things, not only the wearable. Thus, intrinsic motivation to change behavior was a prerequisite for realizing health benefits with the use of the technology.

Moreover, several interviewees commented that using the technology had increased their daily activity levels and encouraged them to become more active because the technology brought visibility to how active or passive the user was during the day. Many of the users argued that without the wearable health data, they most likely would not have put as much thought and effort to being active.

"It motivates you to move more – if I see that I've recorded only a thousand steps I'll definitely go for a walk at the end of the day. But without the technology, not really knowing how many steps you actually have…I think the threshold to take that evening walk would be higher."

Interviewee 9

"It sort of activates you. Like, if you're looking at the previous week or month and you realize your activity level has been very low, it makes you put more effort to being more active."

Interviewee 5

According to multiple interviewees, the use of wearable technology notably increased their daily activity when first adopting the device. Moreover, when first using the technology, many users stated that the goals and reminders on the wearable motivated them to move more. For example, they were motivated to move whenever the wearable recommended that with a notification, or they wanted to reach the daily step goal, no matter what it took. However, through continued use the motivation decreased, reminders were often overlooked, and goals were not perceived as important anymore. Nonetheless, for many of the users that meant, for example, that they simply stopped chasing steps for the sake of recording them on the device. Instead, they understood that it is more important to incorporate activity and other healthy habits to their daily lives in the long term, as opposed to doing whatever it takes to reach the step goal in the short term.

5.5.1 Perceived benefits for exercise workout

Some interviewees used wearable technology particularly for collecting data about specific exercise activities such as strength training, running, or cross-country skiing. The use of wearable technology allowed for collecting workout specific data, such as distance, pace, or heart rate data, which helped the users train better. For example, looking at heart rate data helped the users control their training and exercise at the right intensity, as well as, enabled them to monitor how they were progressing.

Many of the interviewees said that with the help of wearable technology, they were able to keep a precise training diary. With the training diary, the users were able to monitor their progress and plan their future workouts easier. For many, having a training diary was also fun and motivated them to exercise regularly. One interviewee noted that the use of

wearable technology motivated him to exercise more because with the technology, he could easily develop specific and measurable training targets, and monitor those with the data. For instance, the user could come up with the goal of exercising five times per week and skiing 200 kilometers per month. These measurable goals could then be easily monitored by recording the activities with wearable technology and reflected upon from a training diary.

Another aspect of wearable technology that was perceived as a benefit for workouts by some of the interviewees, were the various training programs or coaching functions incorporated in the devices. One of the interviewees stated that in his wearable device, there was a training program for running which would develop a training schedule for the user based on his current health status and future goals. Moreover, the coaching program gave verbal feedback during workouts, helping the user train more effectively. Once the user made progress and reached some of the targets, the program was automatically modified to make sure the workouts were demanding enough for the user.

> *"I'd say there have been health benefits. Especially, when I started that running program with the device, and it developed that training schedule for you, suggesting like, go for this type of run twice a week…it was then quite easy to do once I started that. That was quite a positive thing for me since running itself isn't that fun for me. So, I don't think I would have done that without that type of incentive."*
>
> Interviewee 4

One interviewee also stated that when he was training with a wearable tracker on his wrist, he felt more accountable or responsible to train properly. Similarly, whenever he was exercising without the wearable, he would not go the extra mile and would easily do a lighter workout. The reason was simple – when exercising with the device, the extra effort would be reflected in the data, but when exercising without it, the laziness would leave no trace.

5.5.2 Perceived benefits for better sleep and recovery

All of the interviewees who used wearable technology to record sleep or recovery data stated that it has had a positive effect on their health behavior. The recording of sleep and recovery data increased the awareness of the users and gave them insights from which they understood how to change their health behavior to the better. Some of the interviewees stated that they have lowered their alcohol consumption because through wearable technology use, they have understood how easily it affects their quality of sleep and recovery.

With wearable technology, many of the interviewees had developed a better understanding of their current sleeping habits and of the things that affect sleep quality. One interviewee described that through wearable health data he had gained reassurance on the things that affect sleep and productivity. Through continued use of the technology the users were able to identify how their actions would be reflected in the data, and some interviewees stated that after using the device for a long time, they started to anticipate how their health data would look based on their actions. With that knowledge, the interviewees started to understand what changes in health behavior would positively effect their sleep health, recovery, and energy levels in general.

Some of the interviewees stated that the use of the technology acted as a reinforcing element, a type of promoter of healthy habits. For instance, one interviewee stated that although she understood that there are many benefits of having an early and regular bedtime, she was not sticking to a healthy regular bedtime schedule until she started using wearable technology. For her, seeing the positive effects of a healthy sleep schedule through data helped her change her behavior to the better.

> *"Some of this I would know without the data. Like, I should go to bed earlier. But now since I've had the data, I have started to go to bed earlier. So, when the device prompts me that it would be a good time to wind down and go to sleep, somehow it just works for me."*
>
> Interviewee 1

Many of the interviewees who recorded sleep data stated that having data about their nightly body temperature has had a significant effect on their health behavior. The users understood that whenever their body temperature was on the rise, they might be getting sick, for example. One interviewee noted that having that data was particularly helpful during the pandemic and lockdowns.

> *"If I notice that my body temperature is elevated, I'll take it easy. During covid, I would also not go anywhere because I understood I might be getting sick and I didn't want to infect anyone. Instead, I gave myself permission to rest."*
>
> Interviewee 2

For some of the interviewees, recording sleep, activity and exercise data helped them optimize their training and recovery. Multiple interviewees stated that with those data they could identify the times when they were training too much and did not leave enough time for proper recovery. Training too much – or too little – would often be reflected in their sleep data as well.

> *"It's easy to be blinded by your own behavior. A good example is that I might go skiing 3-5 days in a row, and then suddenly notice that I'm a bit tired and feel like I haven't slept that well. Then I start thinking that maybe it would be a good idea to have a day off, and I realize the device is also screaming that it's time for a day off because my HRV and other metrics are looking awful at the moment."*
>
> Interviewee 12

5.6 Additional thoughts about wearable health technology

At the end of the interview, the interviewees were asked if they had identified any deficiencies or if they had any wishes about wearable health technology which could help promote health behavior change in the future.

Most interviewees stated that the wearables had more than enough functions and that the devices provided more data than they currently even utilized. Many interviewees also noted that they were positively surprised that there was a lot more data available than they would have imagined.

According to some interviewees, the health impact of wearable technology would be even bigger if the tracking was more extensive and comprehensive. One interviewee noted that the validity of the data would increase if the tracking was more extensive, which could in turn promote health behavior change a lot more. For multiple interviewees, longer battery life was the most desirable improvement that would help the extensiveness of the tracking. Many users noted that it was very frustrating and annoying if the battery on the device ran out, for example, just before a workout, resulting in gaps in their health data. Moreover, many interviewees said that they would like to include dietary information in the tracking, but that at the moment that was relatively difficult to do. The dietary tracking would bring visibility to the amount of calories consumed, in addition to the amount of calories burned, making it easier for the users to understand their health behavior, and consequently, to make changes in it.

Moreover, some interviewees hoped that wearable technology would be easier to integrate with other systems. Two interviewees were participating in other health programs, to which they hoped the wearable data could be utilized for, while another interviewee thought that it would help a lot if the wearable could be integrated with some ready-made gym training programs. One interviewee was craving for options to input data about their subjective feelings to the wearable. She suggested that the wearable could, for instance, ask the user about how they are mentally feeling today, and take that data into account when evaluating the state of health of the user.

> *"Health and wellbeing are, after all, much more than just a person's physical entity."*
>
> Interviewee 5

Although most users were satisfied with the amount of data that was available with wearable technology, some hoped for more extensive data and more innovative ways to record it. For example, one of the users who used a smart ring to measure sleep and a sports watch to measure exercise activities, hoped that in the future he could record all the data with the smart ring. Another user stated that he disliked using his device while sleeping and noted that some sort of smart clothing might be more comfortable for tracking sleep data. Furthermore, one interviewee hoped for easier integration between different wearable devices, and that if the battery on one device were to run out suddenly, the tracking could be continued with another device, for example. Therefore, the wish was that there would be as few gaps as possible in the data, making the tracking as continuous as possible. On a similar note, one interviewee noted that currently the data between different wearables varied a lot. According to her, it was sometimes tricky to use multiple devices at the same time because if they didn't sync with each other, the same data would easily be logged twice.

6 Discussion

The purpose of this thesis was to study the perceived health effects of using wearable technology. The term "health" was categorized to include not only physical activity but also subjective wellbeing, quality of life, and sleep among others. The empirical data for the research was collected via semi-structured interviews to gain insights on how people use consumer health wearables and what are the perceived health effects of that use. The main findings of the empirical research revolved around the themes of motivation, use of wearables and analysis of the health data, perceived effect on awareness, and perceived effect on health. In this section, the results presented in the previous chapter are further discussed and analyzed.

When analyzing the interview data, it is best to refer back to the main research question to maintain the focus of the research. The research question for this thesis was:

How do consumer health wearables affect the health and wellbeing of users?

Furthermore, to provide a better answer to the main research question of the study, the following sub-question was formed at the beginning of the thesis:

Does the use of wearables increase the awareness of users' current health behavior, and if so, does this facilitate health behavior change?

The findings from the semi-structured interviews suggest that the use of wearable health technology increases the users' awareness of their own health which further translates to changes in their health behavior. The results indicate that wearable health technology increases the users' understanding of their health behavior by making it visible through data. The increased awareness and understanding of health enables the user to change their health behavior to the better because they understand which actions to take.

6.1 Motivational constructs for wearable health technology use

Based on the findings of this thesis, the main motivational constructs for using wearable health technology include curiosity, personal interest towards health and data, goal-setting, health concerns, and interest in increasing the awareness of one's own health. The most

prevalent motivator for wearable use among the interviewees was general curiosity about the technology to see how the devices work and how those can improve their health. Besides that, the prospect of increasing awareness of the user's current health behavior and the hope for long-term health benefits were among the main motivating factors for the users' wearable use. A number of users also noted goal-setting and personal interest towards data as an important motivator. These findings are in line with prior studies. Shin et al. (2019) state that the primary motivation of quantified-selfers for collecting any personal data is to answer questions about themselves, i.e., curiosity to increase awareness about the self. For the participants in this study, the use of wearable health technology provided answers to questions such as "*how well am I sleeping?"* and *"how active am I on a regular day?"*. In addition to the motivational constructs found in this thesis, Kononova et al. (2019) suggest social support as one of the primary motivators for long-term users of wearables. From the interview participants in this thesis, only one stated social support, such as competition or cooperation with other wearable users, as a motivational factor. This may suggest that Finnish wearable technology users perceive health data fairly personal and are not eager to compare the data with others. Moreover, the participants in this study mostly engaged in casual level individual sports, and recorded health data out of their own interest. Therefore, social support may be more prevalent among users who take part in team sports, or who train more professionally and thus have a more apparent group to share the data with.

The study provides further information on whether the use of wearable health technology is driven by extrinsic or intrinsic motivation. Extrinsic motivation occurs because of external rewards, whereas intrinsically motivated people engage in activities out of authentic interest, and get feelings of enjoyment, satisfaction, excitement, and accomplishment (Kononova et al., 2019). Other reasons to be intrinsically motivated include curiosity and willingness to try something new (Schaffarczyk & Ilhan, 2019). The study participants, who were all long-term users of the technology, were intrinsically motivated to use wearable health technology. This suggests, similarly to prior studies, that long-term usage of wearable technology is driven by intrinsic motivation (Kononova et al., 2019; Schaffarczyk & Ilhan, 2019). Moreover, some of the users were also extrinsically motivated, as they stated that they used the devices because they felt rewarded. This finding is also noted in previous research.

Based on the interviews, the users who were initially motivated to change their health behavior with the help of wearable technology perceived more health benefits from using wearables. All of the users who were highly motivated to change their health behavior with

wearable technology use said that they experienced many health benefits from using the technology. From those who had low motivation to change behavior, half changed their health behavior, whereas half stated that they did not experience any health benefits from using the technology. These findings suggest that people in the preparation stage in Li et al.'s (2010) stage-based model of personal informatics systems are more likely to reach the action stage, if they have high intrinsic motivation to use the system and high motivation to act on the information collected with the system.

6.2 Use of wearable health technology and effect on awareness

The sub question for the thesis was *"Does the use of wearables increase the awareness of users' current health behavior, and if so, does this facilitate health behavior change?"*. Based on the findings, the use of wearable health technology positively impacts users' awareness of their own health behavior. The use of the technology made health "visible" by quantifying everyday matters. For instance, daily activity was indicated by the number of steps recorded during a day, and sleep quality by the hours slept in different sleep stages, among other things. This gave the users an objective, outside view of their health behavior, increasing their understanding of how healthy they actually are. For many, the data supported their subjective feelings and the things they already knew about their health. Moreover, the users noted that their awareness increased especially with the metrics that are hard to measure or evaluate subjectively. Examples of such metrics include, for instance, body temperature while sleeping or the total distance traveled during a week.

The findings indicate that users mostly reflect on very short-term wearable health data. Only few study participants systematically analyzed the long-term trends of their data. For the users, reflecting on the short-term data was more meaningful because they were able to compare that data to their own subjective emotions. For instance, it was easy for the users to reflect on their sleep data right after waking up in the morning because they had a fresh sense of how well they thought they slept and remembered what activities they engaged in the day before. They also felt that they had more opportunities to influence the short-term trends, whereas the long-term trends were perceived as "nice to know" but hard to act on. This implies that wearable technology providers should provide feedback and visualizations on the devices, that are easy to understand and easy to act on for the user to make changes in their health behavior – both in the short-term and the long-term. Moreover, the ready-made metrics such as the Oura Readiness Score and Garmin Body Battery were considered as easily digestible presentations of data that substantially increased the users' awareness of

their health. The Oura Readiness Score is an overall recovery measure that considers various metrics, such as body temperature, lowest overnight resting heart rate, heart rate variability, and sleep and activity balance to form a score (0 – 100) that indicates how well recovered and prepared the user is to tackle the current day's stressors (Oura, 2022). Similarly, the Garmin Body Battery calculates an energy level score (1 – 100) for the user based on their activity, heart rate variability, stress, and sleep (Garmin, 2022). The higher the score, the more energy the user has for completing the tasks of the day. The interviewees considered both of these features very useful because they helped them analyze the wearable data and make better insights. The Oura Readiness Score, for instance, not only displays the overall readiness for the user but all the components that lead to the score. This type of feedback, where the user can get a good understanding of their overall recovery with one glance, and then focus on the individual factors that contribute to the overall score, was considered insightful and helpful for increasing awareness. Figure 5 presents an example of how the Oura Readiness Score is displayed in the Oura app.

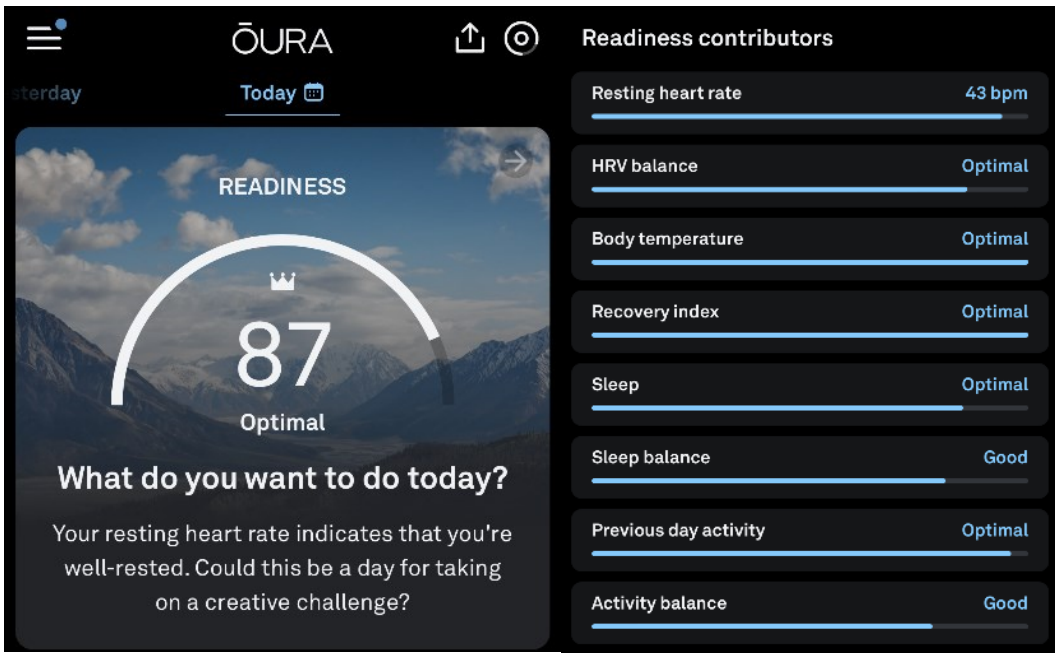

Figure 6. Screenshots from the Oura app: Oura Readiness Score and the readiness contributors.

The interviewees noted that the increased awareness gained from using the technology allowed for making changes to their health behavior. With the new knowledge, they understood what actions to take to improve their health. The finding is in line with Shin & Biocca's (2017) research. They found that users' health consciousness plays a significant

role in health-related behavior – higher levels of health consciousness lead to greater tendency for maintaining health. The finding implies that wearable technology providers should continue to look for ways to provide the data to the users in ways that bring new insights to them and increases their awareness of their health. In terms of Li et al.'s (2010) stage-based model of personal informatics systems, this enables users to move from the stage of reflection to the stage of action.

6.3 Perceived health benefits and changes in health behavior

The main research question of the thesis was "*How do consumer health wearables affect the health and wellbeing of users?"*. The study suggests that the use of wearable health technology results in perceived health benefits and positive changes in health behavior. The perceived health benefits that arose from the interviews include increased activity, smarter training, better sleep, and smarter recovery behavior. The use of wearable technology also increased users' motivation to be physically active and choose healthier habits in general. Many interviewees noted that even if they did not manage to be very active and healthy at all times, they at least put more effort to it and identified the importance of healthy habits such as decreasing sedentary behavior and increasing the amount of sleep. The findings are in large part similar to those of prior studies, which indicate that wearable use has a positive impact on physical health, motivation, and awareness (Tang et al., 2020; Jin et al., 2020; Stiglbauer et al., 2019). On the other hand, the findings on sleep behavior differ from prior research as the interviewees perceived that their sleep behavior improved with the use of wearable technology. Liang & Ploderer (2016) examined the potential of wearables for improving sleep, and while the study participants reported increased awareness of sleep habits, none of them were able to actually improve their sleep. In this thesis, however, the interviewees stated that they were able to analyze the sleep data and make straightforward plans of actions for improving the quality of their sleep behavior. One possible cause for the difference is that Liang & Ploderer's study was conducted over five years before this research. Wearable health technology has undoubtedly improved since then. For instance, the 2nd generation and 3rd generation Oura smart rings, which were the most common sleep tracking devices among the participants of this study, came out in 2018 and 2021, respectively. These devices not only provide good quality data, but also actionable insights for the user to make better behavioral decisions (Oura, 2022). In fact, that may be one of the most important reasons for the difference in the study findings, as Liang & Ploderer stated that the main barriers for improving sleep with wearable technology included not knowing

what normal sleep is, not understanding the reasons for the lack of sleep, and not knowing how to act on the data.

Based on the interviews, the more intensively the user engages with the technology, the greater the perceived health benefits are. Moreover, the users who followed more metrics indicated greater benefits from the use. For example, those who recorded sleep data with the wearable engaged more with the device compared to those who did not record sleep. They also perceived the use of the technology as more beneficial to their health. Stiglbauer et al.'s (2019) research yielded similar results. They found that the stronger the engagement with the wearable and its accompanying app, the more noticeable the positive effects on self-reported measures on health and wellbeing.

As was discussed in the literature review, Oinas-Kukkonen's (2013) model of BCSS's include three types of change – compliance change, behavior change, and attitude change. In this research, all three types were prevalent among the interviewees. A compliance change occurred among the users who where motivated to change their health behavior, but relied on the wearable to guide them how to go about it. Behavior change was prevalent as several interviewees indicated that they made changes to their behavior based on the insights they made from analysing the wearable data. Some users also explicitly stated that the continuous presence of the tracker resulted in an attitude change as they were constantly reminded of the health consequences of their behavior.

The interview participants in this research were all long-term users of wearable technology. The research findings suggest that wearables may help users in the action stage of the stage-based model of personal informatics, and the maintenance stage of the transtheoretical model of behavior change, by providing ongoing feedback and reinforcement of healthy behaviors, helping users to stay motivated, and providing reminders to sustain healthy habits over time.

7 Conclusions

The aim of this thesis was to contribute to the field of wearable technology research by answering the following research question:

How do consumer health wearables affect the health and wellbeing of users?

To answer this question, a qualitative study was conducted with long-term users of wearable health technology. Twelve users were interviewed about their experiences and perceived health effects of using the technology. The findings indicate that the use of wearable health technology increases the users' awareness of their own health which can further translate to changes in their health behavior. The long-term use of the technology, which is driven by intrinsic motivation, reinforces the users' consciousness of their own health and increases their awareness about the health metrics that are hard to evaluate subjectively. With this knowledge, the users are able to change their health behavior and improve their habits, provided that they are motivated to do so.

This study contributes to the field of research related to wearable technology by filling the research gap when it comes to the health effects of using the technology. The amount of academic research on the health implications of wearable technology has been rather limited to date. This study sheds more light on whether wearables are used for simply recording information or for actually changing health behavior. Furthermore, prior studies on the topic have mostly focused on the motivations rather than the health outcomes of using wearables. Many studies have also been limited to certain user groups, such as older adults or people with specific health conditions. This study focused on long-term everyday users of wearables, thus focusing on "regular users", as has been suggested for future research in prior literature. Therefore, the thesis contributes to existing literature by studying those user groups that have not been examined thoroughly in prior research.

The analytical framework of the thesis utilized Li et al.'s (2010) stage-based model of personal informatics systems as a theoretical base, bringing contribution to the research on personal informatics. This theoretical contribution is needed in future research as well, as the theories around personal informatics systems have not yet been extensively utilized in the field of wearable technology research. The analytical framework, which was developed by the author of this thesis, can also be applied, as well as further developed in future research on the topic area. Furthermore, the findings of the study support as well as challenge

the findings of prior research, as was discussed earlier in the discussion section of the thesis. Lastly, there were some practical design implications that can enhance the user experience of wearable technology users. The study provides further information on how wearable users utilize the devices, how they analyze the data, and what functions they are still lacking. This is a valuable insight especially for wearable technology providers and manufacturers. All in all, the thesis provides a comprehensive view of how people use wearable health technology and what are the perceived health benefits of that use.

7.1 Limitations

There are some limitations that should be considered when analyzing the results of this thesis. First, general time constraints and lack of previous research on the topic created some challenges for completing the research. Moreover, all the interviews for this thesis were held in Finland with Finnish citizens. Therefore, the findings may not be accurate outside of Finland. Furthermore, the main criteria for the purposive sample was long-term usage of wearable health technology. Although there was effort to recruit participants with diverse backgrounds, for instance, in terms of age, gender, and sporting history, some groups of people were not as well presented as others. For example, none of the interviewees had small children at home, which could have an effect on the results of the study. Some interviewees even noted that they probably would not have had the opportunity to change their health behavior with wearable use, if their children were still young. Also, due to the rather small sample size the findings are not generalizable. Nonetheless, generalization of the results was not the aim of the study.

7.2 Suggestions for future research

The focus of the study was to examine how the use of wearable technology impacts health and wellbeing. Future studies could take a closer look to explore what are the specific factors that enhance changes in health behavior or what are the barriers that are stopping people from experiencing those health benefits.

There were some indications that there could be some amotivation among some of the long-time users if they are forced to train without a wearable, for example if the device's battery runs out or the wearable is forgotten. Future studies could investigate this issue more.

In this thesis, the study participants were all long-term users of the technology. Future studies could examine what are the main causes why people stop using the technology and may not get all the health benefits realized. Another possibility would be to study those users

who previously used the technology but do not do so anymore – if their behavior changed because of the technology, have those changes endured since?

Future studies could also restrict the variety of devices included in the research or research could be done as a case study to study a particular device, such as the Oura smart ring. A multiple case study with, for example Oura and Garmin wearables, could also yield interesting insights. It could also be researched whether the health impacts differ among different wearable brands.

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Appendix A: Interview Questions

Puettavalla teknologialla tarkoitetaan tässä tutkimuksessa päälle puettavia laitteita, joilla voidaan tutkia käyttäjän käyttäytymistä tai fysiologista tilaa yhden tai useamman signaalin avulla. Esimerkkejä em. laitteista ovat mm. urheilukellot ja Oura-sormukset.

1. Mitä puettavaa teknologiaa käytät ja mitä asioita mittaat?
2. Kuinka kauan olet käyttänyt?
3. Kuinka usein käytät?
4. Mitä mittaat (esim. uni, askeleet, yleinen aktiivisuus, tietyt aktiviteetit/urheilulajit)?

5. Miksi mittaat? Motivaatio puettavan teknologian käyttöön? Mitä haluat puettavalta teknologialta?
6. Miten analysoit laitteen tuottamaa dataa?
7. Katsotko laitteesta suoraan vai synkronoitko esim. puhelimeen tai tietokoneelle?
8. Minkälaisella aikajänteellä analysoit?

9. Onko käyttö lisännyt tietoisuutta omista elintavoista ja terveydestä?

10. Onko puettavan teknologian käytöllä ollut vaikutusta elintapoihin?
11. Koetut terveyshyödyt (esim. aktiivisuustason nousu, palautuminen, uni, suorituskyky)?
12. Liikutko enemmän teknologian käyttöönoton jälkeen?
13. Motivoiko laite liikkumaan tai elämään terveellisemmin?
14. Onko teknologialla myös käänteisvaikutusta eli onko motivaatio alhaisempaa, jos laite ei ole mittaamassa urheilusuoritusta?

15. Mahdolliset puutteet tai toiveet teknologiaan liittyen?