Persuasive Technology for Health Promotion: Post-Adoptive Use, Behavior Change, and Design Guidance

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Research Papers

Research Paper 1	Rieder, A., Lehrer, C., & Jung, R. (2019). Understanding the Habitual Use of Wearable Activity Trackers. *Proceedings of the 17th International Conference on Wirtschaftsinformatik*, Siegen, Germany, pp. 1002-1016.
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Research Paper 3	Rieder, A., Eseryel, U.Y., Lehrer, C., & Jung, R. (2020). Why Users Comply with Wearables: The Role of Contextual Self-Efficacy in Behavioral Change. *International Journal of Human-Computer Interaction*.
Research Paper 4a	Rieder, A., & Rhyn, M. (2020). Situational Self-Efficacy and Behavioral Responses to Wearable Use. *Proceedings of the 28th European Conference on Information Systems (ECIS2020)*, Virtual Conference.
Research Paper 4b	Rieder, A., Shevchuk, N., Oinas-Kukkonen, H., & Jung, R. (2020). The Transient Nature of Self-Efficacy in Technology-Enabled Health Behavior Change. *Working Paper.*
Research Paper 5	Rieder, A., Lehrer, C., & Jung, R. (2020). Affordances and Behavioral Outcomes of Wearable Activity Trackers. *Proceedings of the 28th European Conference on Information Systems (ECIS2020)*, Virtual Conference.
Research Paper 6	Rieder, A., Lehrer, C., Eseryel, U.Y., & Jung, R. (2021). The Generative Mechanisms Behind Technology-Enabled Changes in Health Behavior. *Proceedings of the 29th European Conference on Information Systems (ECIS2021)*, Virtual Conference.
Research Paper 7	Rieder, A. (2020). Design Blueprint for an Adaptive Persuasive Health System. *Working Paper.*

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Abbreviations

cf.	confer
DR	design requirement
DP	design principle
e.g.	for example
et al.	et alii
ibid.	ibidem
i.e.	that is
IS	information systems
p.	page
pp.	pages
resp.	respectively
RP	research paper
RQ	research question
UTAUT	unified theory of acceptance and use of technology

Abstract

An unhealthful lifestyle is one of the key factors of mortality in modern society. Persuasive technologies, information systems that aim to change users' behaviors and attitudes in a predefined way, are increasingly used for health promotion to encourage a physically active lifestyle and healthful nutrition to prevent diseases of affluence. Persuasive technologies for health come in different shapes, though, recent advances in mobile and sensor technologies have given rise to wearable self-tracking devices that have shortly reached high penetration in mainstream markets. While high hopes lie on persuasive technologies to improve personal and public health outcomes and empirical evidence for their effectiveness exists, concerns regarding their capacity to sustainably induce changes in health behaviors are growing. Despite the rich body of literature on the adoption of persuasive technology, gaps in knowledge exist with regard to user's post-adoptive use experiences and behaviors, the processes along which persuasive technologies generate cognitive-affective and behavioral outcomes, and how persuasive technologies can impel such processes in a targeted way.

This cumulative dissertation addresses these gaps and seeks to gain an understanding of post-adoptive use processes, to explain the occurrence of adverse experiences and their effects on users, to explain the outcomes of persuasive technology use, and to generate design knowledge to develop persuasive technologies to achieve long-term changes in health-promoting behaviors. These research objectives are achieved through eight research papers using different research approaches to shed light at different aspects concerning the post-adoptive use, the behavioral outcomes, and the design of persuasive technologies, by applying qualitative and quantitative research methods, and following the design science research paradigm.

The dissertation makes several primary contributions to persuasive technology research: First, users' habit formation processes and adverse experiences are highlighted. Second, the outcomes of persuasive technology use are outlined and mechanism-level explanations for why some users arrive at behavioral outcomes while others do not are provided. Third, by presenting a design artifact, design knowledge for the development of adaptive persuasive technologies for health promotion is generated. Moreover, the findings have important implications for practitioners, in particular, providers of persuasive technology and system designers.

Zusammenfassung

Ein ungesunder Lebensstil ist einer der zentralen Sterblichkeitsfaktoren in der modernen Gesellschaft. Persuasive Technologies sind Informationssysteme mit dem Ziel, Verhaltensweisen und Einstellungen von Nutzer*innen auf vorhersagbare Weise zu verändern. Sie werden zunehmend in der Gesundheitsförderung eingesetzt, um einen körperlich aktiven Lebensstil und eine gesunde Ernährung zu fördern, die massgeblich dazu beitragen können, die Prävalenz von Wohlstandskrankheiten zu minimieren. Persuasive Technologies für die Gesundheitsförderung können verschiedene Formen annehmen. Fortschritte in der Mobil- und Sensortechnologie haben jüngst zur Entwicklung und Verbreitung von Wearable Self-Tracking-Geräten beigetragen, die innert kurzer Zeit die Mainstream-Märkte durchdrungen haben.

Grosse Hoffnungen liegen auf Persuasive Technologies, die persönliche und öffentliche Gesundheit zu verbessern. Während empirische Evidenz für ihre Wirksamkeit vorliegt, kommen unterdessen Zweifel an der Fähigkeit von Persuasive Technologies auf, Gesundheitsverhalten nachhaltig verändern zu können. Trotz der vielfältigen Literatur zur Adoption von Persuasive Technology, existieren Wissenslücken im Hinblick auf Erfahrungen und Verhalten von Nutzer*innen in der Post-Adoptions-Phase, sowie hinsichtlich der Prozesse, entlang derer Persuasive Technologies kognitiv-affektive und verhaltensbezogene Effekte auslösen. Weiter ist unklar, wie Verhaltensveränderungsprozesse durch Persuasive Technologies gezielt angestossen werden können.

Die vorliegende kumulative Dissertation adressiert diese Lücken und hat zum Ziel, ein Verständnis über die Prozesse der Post-Adoptions-Phase zu erlangen, Effekte der Nutzung von Persuasive Technologies zu erklären und Designwissen zur Entwicklung von Persuasive Technologies zu kreieren. Diese Forschungsziele werden durch acht Forschungsbeiträge erreicht, die unterschiedliche Vorgehensweisen verfolgen, um verschiedene Aspekte hinsichtlich der post-adoptiven Nutzung, der Effekte und des Designs von Persuasive Technologies zu beleuchten. Die Projekte nutzen dazu verschiedene Ansätze, verwenden qualitative sowie quantitative Forschungsmethoden, und folgen dem Design-Science-Research-Paradigma.

Die Dissertation macht verschiedene Beiträge zur Persuasive Technology-Forschung: Erstens werden die Prozesse der Gewohnheitsentwicklung und negativer Erfahrungen von Nutzer*innen aufgeklärt. Zweitens werden die Effekte der Nutzung von Persuasive Technology aufgezeigt und Erklärungen auf Basis von Mechanismen aufgestellt, weshalb manche Nutzer*innen Verhalten verändern und andere nicht. Drittens wird in der Form eines Design-Artefakts Designwissen für die Entwicklung von adaptiven Persuasive

Technologies kreiert. Weiter haben die Ergebnisse wichtige Implikationen für Praktiker, insbesondere für Anbieter*innen von Persuasive Technologies und Systemdesigner*innen.

1 Introduction

An unhealthful lifestyle is one of the key factors of mortality in modern society (World Health Organization, 2019, p. 5). Therefore, efforts in health promotion rely heavily on encouraging a physically active lifestyle and healthful nutrition to prevent the appearance of so-called diseases of affluence, for example, high blood pressure, type 2 diabetes, and overweight (World Health Organization, 2014, p. 33). With the advancements in mobile and sensor technologies over the past couple of years, health interventions are increasingly delivered through digital technologies, like wearable self-tracking devices or fitness and nutritional apps (Kraft et al., 2009, p. 401; Coughlin and Stewart, 2016, pp. 1). Having changes in users' health-related behaviors at heart, such technologies are regarded as persuasive technologies (Lehto & Oinas-Kukkonen, 2015, p. 127). Persuasive technologies are socio-technical information systems that aim to change users' behaviors and attitudes in a predefined way (Fogg, 2003, p. 15; Oinas-Kukkonen & Harjumaa, 2009, p. 486). For this, persuasive technologies make use of such persuasion strategies as self-monitoring, goal-setting, and social support to induce behavior change (Lyons et al., 2014, pp. 5).

System providers, public health institutions, healthcare providers, health insurances, and scholars assign persuasive technology great potential to promote healthful behaviors and thus to improve individual and public health outcomes. Empirical studies have proven wearable self-tracking devices to be effective in increasing physical activity and energy expenditure (e.g., Brickwood et al., 2019, pp. 6). Acknowledging the potential, organizations started to leverage persuasive technologies for their occupational health programs (Fingas, 2020; Mettler & Wulf, 2019). Moreover, health insurance companies around the globe added initiatives using persuasive technology to their preventative health efforts, some of them providing financial benefits to individuals who meet certain activity levels (Discovery, n.d.; Wiegard & Breitner, 2019; Kuchler, 2019). However, growing concerns regarding the technologies' capacity to sustainably change health behaviors (e.g., Jakicic et al., 2016, p. 1168) and abandonment after short periods of use (Ledger & McCaffrey, 2014) dampen the prospects, hence raising the questions of how persuasive technologies become entangled in users' lives and how they drive behavior change. While information systems (IS) research has yielded a rich body of literature on the adoption of persuasive technology (e.g., Fox & Connolly, 2018; Lim & Noh, 2017) and user's post-adoptive use behaviors (e.g., Prasopoulou, 2017; Mettler & Wulf, 2019), knowledge regarding the processes of establishing continuous use patterns, the processes along which persuasive technologies generate cognitive-affective and behavioral outcomes, and how such processes can be impelled in a targeted way remains scarce. Thus, I pose the following overarching research questions (RQ):

RQ1: *How do processes behind continuous persuasive technology use unfold?*

RQ2: *How does persuasive technology use give rise to adverse experiences?*

RQ3: *How does persuasive technology use shape users' cognitive-affective and behavioral outcomes?*

RQ4: *How should persuasive technologies be designed to effectively realize changes in users' health-promoting behaviors?*

I answer the overarching research questions through eight research papers that constitute this cumulative dissertation. The empirical research papers address the topics of habit formation, adverse experiences, self-efficacy to change, the role of context, technology affordances, generative mechanisms, and design guidance using qualitative and quantitative methods as well as a design science approach.

I contribute to research on persuasive technology in highlighting users' habit formation processes and adverse experiences. Moreover, I shed light at the differential and variable outcomes of persuasive technology use and provide mechanism-level explanations for why some users arrive at behavioral outcomes while others do not. Additionally, by presenting a design artifact, I generate design knowledge for the development of adaptive persuasive technologies for health promotion. Besides that, my findings have important implications for researchers investigating persuasive technologies and health interventions as well as practical implications regarding the design and evaluation of persuasive technologies.

This dissertation is structured as follows. First, I present the foundations of my research, outlining the core concepts persuasive technology, their application for health, and a synthesis of related work. In section 3, I give an overview of the research objectives and research questions. Section 4 encompasses descriptions of the research papers that constitute this dissertation. Then, I discuss the theoretical contributions of the research, implications for research and practice as well as limitations and avenues for further research.

2 Background

2.1 Persuasive Technology

Persuasive technologies can be defined as IS that are designed to induce changes in users' behaviors and attitudes in predefined ways (Fogg, 2003, p.15; Oinas-Kukkonen & Harjumaa, 2009, p. 486). For this purpose, they incorporate persuasive techniques, like self-monitoring, social support, and gamified elements, such as rewards or challenges (Lyons et al., 2014, pp. 5; Mercer et al., 2016, pp. 4).

Persuasive technologies aim to reach different outcomes. Besides outcomes in which the users alter their behavior, persuasive technologies may also reinforce existing behavioral patterns or encourage users to take up novel behavioral sequences (Oinas-Kukkonen, 2013, p. 1225). For instance, monitoring oneself by tracking one's dietary intake can support the reversal of unhealthful eating habits, while the tracking physical activity may, help users to take up new behaviors by introducing daily walks. Existing behavioral patterns may be reinforced through persuasive technology, for example, by providing users with workout histories, statistics, and leaderboards, thus making regular exercise more appealing.

Moreover, Oinas-Kukkonen (2013, pp. 1225) distinguishes between three types of change induced by persuasive technologies based on their magnitude and fundamentality: Compliance change, behavior change, and attitude change. Compliance change is lowest in magnitude and easiest to achieve, since it involves simple acts of complying with an external (i.e., technological) cue. In contrast, behavior change includes a more fundamental, intermediate- to long-term change in behavioral patterns or routines. Attitude change, the third type of behavioral change, is a cognitive category, which is regarded as an enhancement of behavior change, yet, at the same time as catalyst of behavior change. Oinas-Kukkonen (2013, p. 1226) indicates that behavior change is more likely and more stable if the individual has also changed his or her attitude.

Having outcomes beyond mere IS use at heart makes persuasive technologies a special case of IS. Much of IS research is directed at *technology interaction* when looking at post-adoptive use behaviors (e.g., Jasperson et al., 2005; Saeed and Abdinnour, 2013). While these interaction behaviors can be regarded as the basic level of use, Burton-Jones and Grange (2013, p. 633) argue that in order to obtain benefits from using an IS, it is not enough to use the IS but one has to use it *effectively*, that is, so it helps attain the goals an individual seeks to achieve using it. Barki et al. (2007, pp. 174) describe similar phenomena under the term of *IS use-related behaviors*, referring to activities that users perform in order to employ the technology in a way that allows them to fulfill their tasks. Such activities may include adaptation and learning activities, like reading a manual or communicating with professionals about system modifications (Barki et al., 2007, pp. 175; Burton-Jones and Grange, 2013, pp. 644). Drawing on this line of argumentation as well as established definitions of persuasive technologies (cf. Fogg, 2003; Oinas-Kukkonen & Harjumaa, 2009; Oinas-Kukkonen, 2013), I argue that persuasive technologies target impacting behaviors that lie beyond technology interaction and effective use resp. use-related behaviors. Hence, investigating persuasive technology must target both, use behaviors in the traditional sense (i.e., technology interaction, IS use-related behaviors, and effective use) and the behaviors relating to the area of impact of the persuasive technology.

A popular area of application is the health context, where great hope is placed on persuasive technologies' potential to promote healthful behaviors and thereby improve individuals' health outcomes (Lehto & Oinas-Kukkonen, 2015, p. 127). In this example, technology use in the traditional sense would encompass interacting with the technology, for example, tracking a behavior or checking data, whereas the area of impact may include the changes in individuals' physical behaviors (e.g., activity or nutrition) that are made based on inducements of the technology.

2.2 Leveraging Persuasive Technology for Health

In recent years, the health ecosystem has witnessed profound transformation through digital technologies. Introducing information technology to healthcare organizations has yielded improvements in administrative and clinical processes, such as decision support, clinical documentation, patient support, and enhancements in quality and safety of healthcare (e.g., Dobrzykowski & Tarafdar, 2015; Karahanna et al., 2019; Lin et al., 2017). On the individual side, digitalization has influenced health promotion efforts and catalyzed the development and distribution of persuasive technologies (Lehto & Oinas-Kukkonen, 2015, p. 127). These developments have led to a tremendous number of ventures providing personal tracking technology for use in different domains of health promotion, such as, nutrition, physical exercise, sleep, and mental health and incumbent companies from different industries (e.g., Apple, Samsung, Nike, Polar, health insurance companies) have jumped on the bandwagon (Phaneuf, 2019). Striking growth rates (IDC, 2020) and an immense mainstream penetration—more than 80% of consumers indicated to use digital tools (i.e., mobile applications and wearable technology) to manage their health (Accenture, 2018)—characterize the market.

Besides these economic potentials, persuasive technologies promise the potential to overcome diseases of affluence—one of the main societal challenges of the twenty-first century and a key factor of mortality worldwide (World Health Organization, 2019, p. 5). Diseases of affluence are non-communicable diseases like overweight, type 2 diabetes, and raised blood pressure that are caused by an unhealthful lifestyle, characterized by unhealthful nutrition, low levels of physical activity, and a sedentary behavior (World Health Organization, 2014, pp. 33). According to the World Health Organization (2014, pp. 33; 2010, pp. 10), insufficient physical activity is one of the top risk factors for global mortality and causes more than three million deaths per year; the risk of mortality is increased by up to thirty percent for inactive individuals as compared to individuals with moderate levels of physical activity (World Health Organization, 2014, pp. 33). While impairing the quality of life of those affected, diseases of affluence also induce significant strain on the public health system by increasing the cost of healthcare and related social costs (e.g., European Commission, 2020; Vandenberghe & Albrecht, 2019). To prevent these detrimental outcomes, public health and research efforts have been directed toward health promotion. Delivery of health interventions via digital technologies holds multiple advantages over traditional approaches, such as, scalability, lower intervention cost, the possibility to individually tailor interventions based on personal sensor data, harnessing a person's social resources through incorporating online social networks, and the use of a wider variety of persuasion strategies (Fogg, 2003; Coughlin & Stewart, 2016, pp. 1; Lyons et al., 2017, p. 2).

Persuasive technologies for health come in different shapes (e.g., computer programs, mobile apps, wearable self-tracking devices) (cf. Fogg, 2003, p. 10) and target various health-related behaviors (e.g., physical activity, nutrition, sports, sleep, mental health, disease self-management) (Lehto & Oinas-Kukkonen, 2015, p. 127). The recent advances in mobile and sensor technologies have given rise to a specific class of persuasive health technologies: wearable self-tracking devices, or simply wearables (Prasopoulou, 2017, pp. 287). Wearables are composed of physical and digital artifacts (Benbunan-Fich, 2019, p. 257). In the physical sphere, sensors are interwoven into objects (e.g., wristbands, clothing) that are worn on the body—as opposed to being carried around—thereby allowing for the measurement of body functions (e.g., heart rate, acceleration, sleep) (Mettler & Wulf, 2019, p. 246). In the digital sphere, the sensor data is paired with data analytics and machine learning applications, which create aggregations and display the obtained information to the user, either directly via wearable interfaces or using accompanying software programs on smartphones or computers (Benbunan-Fich, 2019, p. 257). Given wearables' pervasiveness and their proximity to the human body, wearables represent ideal means to deliver persuasive content aiming to improve health outcomes, such as by increasing physical activity or fostering a healthful diet (de Moya & Pallud, 2020, p. 3).

2.3 Related Work

The academic discourse on persuasive technologies in the health context has seen an immense growth in recent years which has led to the emergence of four major streams of literature. Articles can broadly be clustered into (1) articles on adoption, (2) articles on post-adoptive use, (3) articles on the outcomes of use, and (4) technology-centric design articles. In the following, I will briefly outline the main findings for each stream of literature and highlight the specific gaps in knowledge related to these streams. A tabular overview of the related work can be found in the Appendix.

2.3.1 Persuasive Technology Adoption

Research on adoption of persuasive technologies in the health context encompasses a number of studies investigating the factors supporting or hindering individuals' adoption decision-making and adoption intentions. Most of these articles built upon the established IS theories covering technology adoption (i.e., the technology acceptance model (Davis, 1989) and the unified theory of acceptance and use of technology (Venkatesh et al., 2003)) and found support of the established antecedent factors ease of use, usefulness, subjective norm, and attitude towards the technology in the context of persuasive technology—mostly of the form of wearable self-tracking devices (cf. Lunney et al., 2016; Chuah et al., 2016; Kari et al., 2016; Pfeiffer et al., 2016). Furthermore, a handful of articles identified additional factors that influenced users' adoption intentions. Kim and Park (2019) highlighted the role of hedonic values in persuasive technology adoption by showing that coolness, consisting of attractiveness and originality positively affected users' attitudes and adoption intentions. Chuah et al. (2016) investigated users' perceptions of smartwatches and showed that when smartwatches were regarded as a fashion accessory, visibility was a stronger determinant of adoption, whereas when the technology was in focus for users, usefulness was more important for adoption decision-making. Moreover, Kari et al. (2016) showed that users often assigned persuasive technologies the potential to support self-improvement and having a confirming resp. disconfirming experience with that respect determined whether the technology was adopted or rejected. Last, a study by Lee and Lee (2018) found positive associations between adoption intentions and the factors user awareness of wearable activity trackers, consumer attitudes, personal innovativeness, and health interests.

A handful of studies took a more specific turn on persuasive technology adoption. Focusing on older adults, Fox and Connolly (2018) found that privacy concerns, mistrust, and perceived inability to adopt played a major part in hampering the adoption of mobile health technologies for this user group. Drawing on the prospect theory, Lim and Noh (2017) showed that harnessing gain-framed messages was preferable over loss-framed messages, since they yielded positive intentions toward adopting fitness apps and taking up preventative health behaviors. Last, Liu et al. (2014) investigated the use of loyalty rewards for an e-health program and concluded that they were highly effective in fostering users' enrollment, but not in later stages of use.

In sum, there is a solid body of knowledge on persuasive technology adoption that found support of established IS adoption theories in this context and identified additional factors that are more specific to the context of persuasive technologies, specific user groups, and specific properties of these systems. Hence, the need and potential for further research in this stream is limited. This conclusion is underscored by the overwhelming market penetrations for certain forms of persuasive technologies (e.g., wearable self-tracking devices, fitness apps) which reach up to 20% in the US market, highlighting that, in general, adoption is not a central issue (Statista, 2020).

2.3.2 Post-Adoptive Persuasive Technology Use

The second stream of literature encompasses articles on the post-adoptive use of persuasive technology. They can be further categorized into articles taking a variance-perspective on the predictors of continuous use resp. abandonment of persuasive technologies and articles more deeply investigating users' behaviors and experiences.

Drawing on the IS continuance model, Nascimento et al. (2018) identified additional predictors of smartwatch continuance, i.e., habit, perceived usability, and perceived enjoyment, thereby contrasting utilitarian and hedonic values. They found habit to have an exceptionally strong effect when users experienced low satisfaction (ibid.). Rockmann et al. (2018) found that users' continuance intentions were not only influenced by emotions related to technology use, but also by affective states independent of the technology; unrelated emotions were thereby concluded to carry over and shape the enjoyment and usefulness associated with technology use. In a different effort, Matt et al. (2019) identified various determinants of continuous use behaviors related to wearable activity trackers: besides perceived benefits (e.g., performance expectancy, social image, and hedonic motivation) and perceived deficiencies (e.g., limited reliability, and functional constraints), they found perceived privacy to be an important predictor of continuous use. On the discontinuance-side, Attig and Franke (2020) investigated users' reasons for abandoning wearable activity trackers and indicated that motivation loss, measurement issues, aesthetics and discomfort, obsessive tracking behaviors, and—corroborating the findings by Matt et al. (2019)—privacy concerns were key factors for discontinuance. Moreover, Rockmann (2019) showed that some features of fitness apps thwarted users competence needs, which negatively affected the continuance intentions of users with lower levels of exercise self-efficacy.

Turning towards the second perspective of use behaviors, a number of studies took a more nuanced look into users' experiences and behaviors when using persuasive technologies. Three articles dealt with users' motivations. Gimpel et al. (2013) investigated users' motivations for self-tracking, identifying five distinct motivation types, i.e., self-entertainment, self-association, self-design, self-discipline, and self-healing, indicating that more than one motivation may co-occur and lead to increased tracking behavior. Two studies by James et al. (2019a) and James et al. (2019b) took a slightly different turn, examining how exercise goals and exercise motivation influenced users' feature set selection, finding that intrinsic goals and motivation types were associated with use of data management features, while users with extrinsic goals and motivation types additionally used exercise control and social features (James et al. 2019a).

The remaining articles focused on the phenomena occurring during users' continuous use processes. In an ethnographic study, Prasopoulou (2017) described the continuous entangling process of technology in users' everyday lives, based on long-term use experience of a wearable activity tracker. Mettler and Wulf (2019) used an affordance perspective to identify users' mental models, i.e., users' viewpoints, when facing the introduction and using wearables in occupational settings. Based on the mental models that were shared across users, they derived five user types with distinct sets of affordances and constraints, thereby highlighting the critical role of users in corporate health initiatives. Benbunan-Fich (2019) investigated experience reports by users of minimalist wearable devices and concluded that usability-related failures that were related to the devices minimalistic characteristics hampered the devices capacity to fulfill its mediator role between users and software applications. Focusing on use experiences, Sjöklint et al. (2015) outlined that self-tracking devices enabled multiple positive developments by enabling users to explore previously hidden personal aspects, to gather personal data, and to raise awareness and motivate behavior change. At the same time, they highlighted the dualistic nature of self-tracking by identifying various coping tactics (e.g., disregard of the data, procrastination, selective attention, and neglect) that were employed by users as a response to conflicts between rational and emotional reactions (ibid.).

In summary, reviewing the literature on persuasive technology use sheds light on two specific gaps. First, while there is a comprehensive picture of the factors influencing continuous use and abandonment of persuasive technologies, the dynamics are not fully understood. Since these studies employ a variance-perspective, the processes behind persuasive technology use that allow for explaining how continuous use unfolds are left unexplained. However, from a design-perspective, an understanding of these processes is essential to the development of superior technology. Second, while most of the experience-based studies identify dualistic patterns in persuasive technology use (i.e., affordances vs. constraints, affordance failures, coping tactics), the efforts to specifically examine adverse experiences are limited. However, exploring and understanding the nature and reasons behind dualistic and adverse experiences is needed to identify measures to mitigate these experiences or support users in overcoming them.

2.3.3 Outcomes of Persuasive Technology Use

Articles on the outcomes of persuasive technology use can be clustered into two broad categories. The first category encompasses studies assessing the effectiveness of persuasive technologies to alter certain outcomes, by means of experiments and randomized controlled trials mostly in die field of medical research. The second category, which most IS articles fall under, take a more differentiated turn on outcomes, investigating the behavioral as well as cognitive-affective outcomes of persuasive technology use.

Commonly, studies in the first category of articles stem from medical research and employ quantitative methods allowing for pre- and post-intervention evaluations of specific health-related outcome measures. The article by Finkelstein et al. (2016) is a good representative for the schema used in this category: Over a 6-months-period, they distributed wearable activity trackers and assessed the effect of the intervention with regard to such outcome measures as minutes of physical activity, number of steps, weight, and blood pressure at the end of the 6-months-period as compared to the baseline and a control group. Some articles focused on specific socio-demographic groups (e.g., young men: Ashton et al., 2017; office workers: Brakenridge et al., 2016) or specific health conditions (e.g., mental illness: Naslund et al., 2016; breast cancer: Hartman et al., 2018). Brickwood et al. (2019) conducted a comprehensive review and meta-analysis of a total of twenty-six randomized controlled trials examining the effects of wearable activity tracker-mediated preventative health interventions, coming to the conclusion that utilizing wearable activity trackers as an intervention component can significantly increase users' engagement physical activity. Hence, despite the optimism related to wearable technologies' capacity to increase physical activity, reduce sedentary periods, and caloric expenditure, skepticism is raised regarding improvements to users' physical activity levels, aerobic fitness, body weight, and body composition (e.g., Slootmaker et al., 2009; West et al., 2016) and specifically with regard to the sustainability of the effects over longer periods of time (cf. Jakicic et al., 2016). While highlighting contrasting and sometimes ambiguous results, the methods employed in these studies do not provide any insights into the processes occurring alongside technology use that may offer explanation for the observed outcomes.

In contrast, the second category of articles provides a more theoretically grounded turn to investigate the outcomes of persuasive technology use, aiming to offer explanation for why certain outcomes are observed. Focusing on the cognitive and emotional effects of wearable use, de Moya and Pallud (2020) indicated that wearable use inflicted conflicting effects on users. While wearables were found to empower users by enabling them, for example, to improve themselves, wearables also disempowered users through the constant self-imposed surveillance (ibid.). Two studies by James et al. (2019a) and James et al. (2019b) examined the effects of using fitness technology on users' psychological well-being. Drawing on organismic-integration theory—a sub-theory of self-determination theory—, positive well-being outcomes were found with users with a tendency toward more autonomous motivation types as well as amotivation, while a negative relationship with wellness outcomes was observed with less self-determined users (James et al., 2019b). Similar outcomes were observed in the study by James et al. (2019a) using the slightly different angle of goal content theory—another sub-theory of self-determination theory: Psychological well-being effects were found to vary based on users' exercise goals. Following more extrinsic goals was associated with less psychological well-being than following intrinsic goals (ibid.). In highlighting these complex relationships between use and psychological outcomes, these studies further corroborate the dualistic nature and complexity of outcomes. A recent study by Ogbanufe and Gerhart (2020) on smart watches highlighted both cognitive and behavioral outcomes. They found that the strength of the position of the smart watch with regard to users' identity was associated with more profound ways of using the devices. Also, a strong position in users' identity was associated with exploring new ways to employ devices to improve individual performance, thereby shaping outcomes (ibid.). However, the study focused on smart watches and their broad range of features (e.g., text messages, calendar). Therefore, the use of persuasive health features and health behaviors and outcomes were not at the center. Last, Bhattacharya et al. (2018) set out to investigate the occurrence of pivotal experiences (i.e., specific experiences that lead to a decision to change) in persuasive technology use. Besides identifying factors that lead to pivotal experiences with users, they highlighted the role of the technology in these pivotal experiences: Rather than actually causing the pivotal experiences, technology helped users recognize and reinforce the pivotal moments and supported them in identifying and pursuing the consequent behaviors (ibid.).

While, at first sight, these studies seem very different with respect to their findings, they share the commonality of underpinning dual effects and complexly interwoven relationships between users and persuasive technologies. The ambiguity and complexity of outcomes is underscored by the inconsistent results obtained in trials from the medical sciences. Hence, to fully grasp the seemingly fuzzy, ambiguous, and highly complex relationships of persuasive technology use and its outcomes, insights into the cognitive and behavioral outcomes of persuasive technologies and the processes along which they arise are needed. Such an understanding is necessary to explain why some users arrive at certain outcomes following persuasive technology use while others do not and to be able to design persuasive technologies to actively support or prevent the occurrence of certain outcomes.

2.3.4 Design of Persuasive Technology

The last research stream on the design of persuasive technology includes articles that offer more comprehensive guidance regarding the design of persuasive technologies and articles which focus on individual design-related aspects of persuasive technologies.

The 'persuasive systems design model' (Oinas-Kukkonen & Harjumaa, 2009) represents a particularly well-established guideline for the design of generic persuasive technologies. Besides emphasizing the importance of considering the tenets of persuasive technologies (e.g., non-neutrality, incrementality of persuasion, unobtrusiveness) and the idiosyncrasies of the context for which the system shall be designed, a catalogue of strategies from four categories (i.e., primary task support, dialogue support, system credibility support, social support) as well as guidelines for implementation and evaluation are offered. Offering more concrete guidance with regard to health behaviors, Pinder et al. (2018) synthesized established behavior change theories (e.g., goal-setting theory, dual process theory) into the 'habit alteration framework' which devises on components, intervention points, and principles for digital interventions that aim to tackle users' habits and offered an immense list of real-world examples using the portrayed components. Moreover, Chatterjee et al. (2018) designed, implemented, and evaluated a persuasive system for diabetes self-management. The design artifact consisting of persuasive messages, a sensor system, and a predictive analytics tool was shown to have promising effects on patients' health-related indicators (e.g., steps per day, weight, blood glucose, and idle time) (ibid.).

The remaining design-related articles cover more specific aspects of persuasive technologies. Kaptein et al. (2015) derived requirements for the personalized design of persuasive technologies, indicating that persuasive technologies should be able to identify individual users and measure user traits, and have the capacity to present users with suitable persuasion strategies that allow for causally explaining behavior changes. Building on the tensions present with wearable use in occupational settings, Yassaee et al. (2019) developed design principles to overcome these tensions. Tensions were identified with respect to users' values (i.e., privacy vs. well-being), actions, and roles (i.e., work vs. leisure activities resp. roles). They argue that digital occupational health systems should meet the principles of social fairness, social presence, social response, interruption management, and redefine structural and personal roles to mitigate strains and fulfill their value proposition (ibid). Last, Michie et al. (2013) presented a taxonomy encompassing a total of ninety-three techniques that persuasive technologies can make use of to induce behavioral changes with users. While the taxonomy represents a great source of inspiration for intervention and system designers, no guidance is offered on how to purposefully and context-sensitively select and combine the described techniques.

While some of the principles described in the persuasive systems design model (Oinas-Kukkonen & Harjumaa, 2009) which is a generic framework, are not specified enough for the personal health context, the artifacts (cf. Chatterjee et al., 2018; Pinder et al., 2018; Yassaee et al., 2019) that are tailored to more specific problems in the personal health context (i.e., diabetes self-management, forming and breaking habits, occupational health), are not generic enough for application related to health promotion in more general terms resp. for the development of a more comprehensive system. While these approaches are certainly of great help in informing the design of persuasive technologies, the specificities of problems related to the domain of health promotion require more differentiated design knowledge and guidance on how to develop a system fit to accompany users through the process of health behavior change to improve long-term outcomes.

3 Research Objectives and Research Questions

Building on the gaps in research identified in the preceding section, I will briefly outline my research objectives and the respective overarching research questions that I address in this dissertation (cf. Table 1: Research gaps, research objectives, and overarching research questions

As stated in the preceding section, the potential to generate valuable theoretical and practical contributions to the adoption literature is very limited, since the rationale is well-understood, and issues are rather negligible and seem to be attributable to contexts. However, turning toward the literature on post-adoptive use, outcomes, and design of persuasive technology for health promotion, relevant research problems remain unanswered and hold promising opportunities for research.

First, continuous use represents an important precursor in achieving health-promoting effects from persuasive technologies. While several factors impacting users' continuance intentions have been identified in the literature, the dynamics of developing continuous use behaviors are not fully understood. Thus, I seek to gain an understanding of the processes along which continuous use evolves. I address this research objective through my first overarching research question: *How do processes behind continuous persuasive technology use unfold?*

Second, while research noted the existence of dualistic patterns in post-adoptive persuasive technology use, limited efforts were directed toward explaining the occurrence of adverse experiences. I consider exploring and explaining users' adverse experiences from persuasive technology use crucial for explaining the emergence of non-linear or discontinuous use patterns and for developing measures to counteract such experiences. Hence, I seek to find explanation for the occurrence of adverse experiences and their effects on users. For this, I pose the following overarching research question: *How does persuasive technology use give rise to adverse experiences?*

Third, describing ambiguous outcomes of persuasive technology use which underscores the complexity of the outcomes reveals a lack in understanding the link between technology use and cognitive-affective and behavioral outcomes with users. However, such an understanding is necessary to explain why some users arrive at certain outcomes while others do not. Therefore, I aim to understand the nature of outcomes of persuasive technology use and provide in-depth explanation of the (non-) occurrence of specific outcomes. Thus, my third overarching research question asks: *How does persuasive technology use shape users' cognitive-affective and behavioral outcomes?*

Fourth, given the specificities of behavior change in the domain of health and the need for behaviors to be sustained over long periods of time, I seek to generate design knowledge with respect to achieving long-term changes in health-promoting behaviors through persuasive technology. My last overarching research question asks: *How should persuasive technologies be designed to effectively realize changes in users' health-promoting behaviors?*

Streams of persuasive technology literature	*Research gaps*	*Research objectives*	*Overarching research questions*
Post-adoptive use	Dynamics of developing continuous use behaviors.	Understand processes along which continuous use evolves.	How do processes behind continuous persuasive technology use unfold?
	Occurrence of adverse experiences.	Explain occurrence of adverse experiences and consequent effects on users.	How does persuasive technology use give rise to adverse experiences?
Outcomes	Link between use and cognitive-affective and behavioral outcomes.	Understand nature of outcomes of persuasive technology use. Explain (non-) occurrence of specific outcomes.	How does persuasive technology use shape users' cognitive-affective and behavioral outcomes?
Design	Inducing long-term changes in health-promoting behaviors.	Design knowledge for achieving long-term changes in health-promoting behaviors.	How should persuasive technologies be designed to effectively realize changes in users' health-promoting behaviors?

Table 1: Research gaps, research objectives, and overarching research questions.

4 Research Papers

This cumulative dissertation encompasses eight research papers (RP) through which the four overarching research questions are addressed. Table 2 below gives an overview of the overarching research questions and the respective research papers. The first overarching research question is addressed in research paper 1 which investigates the process of users' habit formation when using wearable activity trackers. The second overarching research question is tackled by research paper 2 which explores users' adverse experiences from using persuasive technology through the technostress lens. Since the third overarching research question is more extensive, facets of it are addressed through five different research papers that use different angles and methods for the problem. Research paper 3 explores the role of users' internal and external context in influencing their perceptions of self-efficacy and subsequent behaviors responding to persuasive technology use. Research papers 4a and 4b take up the perspectives of context and self-efficacy from research paper 3 and quantitatively investigate the transient, i.e., situationally variable, nature of self-efficacy related to persuasive technology. While research paper 4a is a pilot study, 4b represents the full study with the same focus. Research paper 5 examines the affordances of using wearable activity trackers and their associations with specific use behaviors and behavioral outcomes. Research paper 6 unveils the generative mechanisms that drive use behaviors and give rise to cognitive and behavioral outcomes employing a critical realist stance. The fourth overarching research question is addressed through research paper 7 which follows the design science research paradigm and develops a blueprint for designing adaptive persuasive health systems.

In the following sub-sections, each research paper is summarized briefly. The full manuscripts can be found in the Appendix.

Overarching research questions	*Addressed by …*	*Paper title*
How do processes behind continuous persuasive technology use unfold?	RP 1	Understanding the Habitual Use of Wearable Activity Trackers.
How does persuasive technology use give rise to adverse experiences?	RP 2	Technostress from Persuasion: Wearable Users' Stressors, Strains, and Coping.

How does persuasive technology use shape users' cognitive-affective and behavioral outcomes?	RP 3	Why Users Comply with Wearables: The Role of Contextual Self-Efficacy in Behavioral Change.
	RP 4a	Situational Self-Efficacy and Behavioral Responses to Wearable Use.
	RP 4b	The Transient Nature of Self-Efficacy in Technology-Enabled Health Behavior Change.
	RP 5	Affordances and Behavioral Outcomes of Wearable Activity Trackers.
	RP 6	The Generative Mechanisms Behind Technology-Enabled Health Behavior Change.
How should persuasive technologies be designed to effectively realize changes in users' health-promoting behaviors?	RP 7	Design Blueprint for an Adaptive Persuasive Health System.

Table 2: Overarching research questions and respective research papers.

4.1 Paper 1: "Understanding the Habitual Use of Wearable Activity Trackers"

Motivation: Starting from the low rates of continuous use (IDC, 2018; Ledger & McCaffrey, 2014), this research project looks into habitual wearable activity tracker use. Even though habit is seen as an important driver of continuous use (Bhattacherjee & Lin, 2015; Limayem et al., 2007), the processes of IS habit formation are underexplored. Building upon the IS habit formation model by Eyal (2014) and the psychological reference literature (Lally et al., 2010; Neal et al., 2006; Schultz, 2006; Verplanken & Aarts, 1999), the paper aims to investigate the mechanisms behind forming habitual wearable activity tracker use in answering the research question: *What are the underlying mechanisms of habitual wearable activity tracker use?*

Method and approach: Narrative interviews with ten Switzerland-based wearable activity tracker users were conducted. The interview technique was well-suited to obtain a longitudinal picture of the individual use histories, which served the goal of untangling the habit formation processes present in wearable activity tracker use. Using narrative coding (Chatman, 1978), the central sequences of events were identified, allowing for the extraction of two habit formation mechanisms.

Results: Two mechanisms of habitual wearable activity tracker use were identified from the interview data. First, habitual wearable activity tracker use was driven by users' offline habits performed independently of technology use. Second, the wearable activity trackers themselves fostered habitual use by sending out cues and triggers. Based on these drivers, five composed narratives were constructed which follow the process steps of the IS habit formation model (i.e., trigger, action, reward). Additionally, for each of the narratives, a set of interrupting factors were identified that had the potential to bring the habit cycle to a halt. These interrupting factors took different shapes: for example, triggers could be affected when underlying habits changed or rewards forfeited their significance as their novelty value gradually declined.

Theoretical contribution: First, the study contributes to the IS habit literature (e.g., Bhattacherjee & Lin, 2015; Limayem et al., 2007) by unveiling the processes by which use habits are formed in the wearable activity tracker context. Thereby, insights into the antecedent conditions of IS habits are provided. Second, the study contributes to wearable-specific research by describing habit-formation processes and the habitual use of wearable activity trackers. It can be argued that wearable activity tracker use is different from conventional IS use, since they aim to induce offline behaviors. In contrast to prior research, which highlighted technological factors as main interrupters, this research further highlights that most interrupting factors actually reside with users.

4.2 Paper 2: "Technostress from Persuasion: Wearable Users' Stressors, Strains, and Coping"

Motivation: The subject of adverse effects related to the use of persuasive health technologies is receiving growing attention by IS researchers. Recent studies have noted the importance of looking into the adverse cognitive and behavioral effects of using them (Schmidt-Kraepelin et al., 2019). Prior research indicated that users' motivation (Schmidt-Kraepelin et al., 2019), continuance intentions (Rockmann, 2019), achievement of exercise goals (Liu et al., 2016), and wellness outcomes (e.g., James et al., 2019b) may be negatively affected by persuasive technologies. Hence, a more comprehensive understanding of users' adverse experiences is needed to leverage the technologies full behavior changing potential. In this paper, the following research question is addressed:

Why do users encounter adverse effects when using persuasive technology? The technostress perspective (cf. Ayyagari et al., 2011; Tarafdar et al., 2017) is used as a lens to identify the processes along which users experience adverse effects, that is, what causes them, the patterns of use and adversity they generate, and the coping reactions to which they give rise. Technostress is conceptualized as the process in which individuals evaluate a technology's characteristics in terms of whether stressors are present that may give rise to strains (Ayyagari et al., 2011).

Method and approach: Using wearable self-tracking devices as the research context, narrative interviews with twenty-five long-term users of commercially available wearable devices were conducted. The qualitative approach was selected in order to obtain rich descriptions of individuals' adverse experiences (Küsters, 2009; Myers, 1997). To analyze the data, the procedure for interpretive data analysis proposed by Corbin and Strauss (2008) was followed. First, through open coding, concepts related to instances of adverse effects from wearable use were identified. Second, in a step similar to axial coding, the identified categories were organized to represent the sequential pattern of events in the data. This step was sensitized by the technostress concept. In the last step, the data was revisited for accounts of contextual information, and drivers and motivations of use.

Results: The data analysis revealed that the interviewees had experienced adverse effects that are closely related to the concepts of technostress. While the instantiations corresponded with the concepts from the technostress perspective, their sequence was slightly different. The data indicated that technostress is a circular process that users undergo multiple times. As the situations and occurrences of stressors and strains were repeated, learning and anticipation became important elements in shaping users' coping behaviors to avoid the anticipated strains. Users employed various coping strategies: Besides beneficial cognitive strategies, such as, tolerance of the shortcomings or alternative sources for confirmation, users also employed malicious strategies that negatively affected their interaction behaviors (e.g., mental distancing) or had detrimental effects on their physical or psychological outcomes (e.g., obsessive tracking). Two distinctive technostress patterns emerged from the data—control stress and validation stress—that were related to different drivers of wearable use. Control stress arose from users' drive to steer themselves and their performance, while validation stress was related to users' pursuit of recognition and approval from the wearable.

Theoretical contribution: The study makes two primary contributions to research. First, it contributes to research on persuasive technology in the health context by providing insights into the under-researched area of adverse effects. Focusing on continuous, long-term users, the results emphasize the importance of users' having adverse effects on the radar, even when they are continuous users. Consequently, considering adverse experiences and effects should be central when assessing the success of persuasive health technologies. Second, the findings extend the technostress literature by shedding light at the specific coping strategies that users employ. While some users use beneficial behaviors to cope with technostress from persuasive technology use, other coping behaviors are detrimental to the users' relationship with the technology. Such harmful coping strategies should be regarded as serious threats to sustainable and purposeful use, not only to continuance. Therefore, researchers who adopt the technostress perspective should assign a greater role to users' learning and anticipation processes that result in the development of coping strategies.

4.3 Paper 3: "Why Users Comply with Wearables: The Role of Contextual Self-Efficacy in Behavioral Change"

Motivation: In the context of wearables and health apps, contrasting study results (Brickwood et al., 2019; West et al., 2016) and doubts about the long-term effects (Jakicic et al., 2016) have raised skepticism regarding the technologies' capacity for positive behavioral outcomes, especially given reports of high levels of abandonment (Ledger & McCaffrey, 2014). This research seeks to investigate the behavioral and contextual factors that influence users' compliance with wearables as the first step in long-term behavioral change using the concept of self-efficacy (Bandura, 1977), i.e., a person's confidence in their ability to perform a behavior, which represents an important antecedent to behavior. Context (cf. Scharfstein, 1989) is regarded as an enabler of or a barrier to self-efficacy and compliance with the wearable. Hence, the following research question is addressed: *How does context influence wearable users' perceptions of self-efficacy and compliance with wearables?*

Method and approach: A qualitative approach was sought to obtain full and rich personal accounts. Narrative interviews with twenty-five long-term users of wearables based in Switzerland were conducted (Küsters, 2009; Myers, 1997). The two-phased data analysis process followed Miles and Huberman (1994). In the first phase of the analysis, self-efficacy perceptions using categories from self-efficacy theory were coded for deductively. Moreover, behavioral outcomes and contexts were extracted from the accounts. In the second phase of the analysis, the existing codes on behavioral outcomes and context were enriched with descriptive coding (Myers, 2009).

Results: Two types of context emerged from the data: internal and external. The internal context refers to users' internal processes which reside with the users' sphere of action, and originate from their personalities, individual characteristics, and experiences. In contrast, external context refers to the factors that reside outside the individual and influence their self-efficacy. Examples of external contexts include schedule-related restrictions limiting circumstances, and activity patterns. The data showed that internal and external contexts can influence individuals' self-efficacy both negatively and positively. While interviewees referred to certain contexts as contributing positively to their self-efficacy and influencing their compliance with the wearable, they identified other contexts as reducing their self-efficacy and compliance with the wearable. Moreover, interactions between internal and external contexts were found. Internal and external contexts compounded each other, i.e., when external context is negative, negative internal context amplifies this effect. However, positive internal context can also have a neutralizing effect on negative external context. Last, the data revealed that users' self-efficacy was not stable over time. Despite high self-efficacy perceptions regarding a specific behavior in one situation, the same user may have low self-efficacy in another situation with respect to the same behavior.

Theoretical contribution: The study contributes to wearable-specific research in explaining the role of context in forming self-efficacy perceptions and behavioral reactions. Moreover, by showing how internal and external contextual effects can interact in a compounding or neutralizing way, this research extends the understanding in IS research on context (cf. Avgerou, 2019). Last, the findings of this study underpin the transient, context-dependent nature of self-efficacy perceptions thus highlighting the importance for a varying construct.

4.4 Papers 4a and 4b: Longitudinal Studies on the Situational Nature of Self-Efficacy from Persuasive Technology Use

Research papers 4a and 4b quantitatively investigate the transient, i.e., situationally variable, nature of self-efficacy and behavioral responses related to persuasive technology. Since research paper 4a is the published pilot study and 4b represents a working paper of the full study with the same focus, both papers share the objectives, motivation, and approach, so I present them together.

Motivation: Despite the manifold application areas and confirmed potential of persuasive systems in some contexts (e.g., Lehto & Oinas-Kukkonen, 2015; Kuonanoja et al., 2015), their capacity to effectively induce changes in users' health behaviors continues to be contested (e.g., Jakicic et al., 2016). A person's self-efficacy perceptions represent one of the key determinants of subsequent behavior. Persuasive systems have been shown to influence users' self-efficacy with respect to physical health behaviors (Rieder et al., 2020a). In addition, various factors from users' internal and external contexts have been identified to play an important part in supporting and restricting self-efficacy perceptions and behaviors related to persuasive systems use (ibid.). Hence, this study seeks to further the understanding of the complex relationship between persuasive systems use, the context surrounding users, and the effect on self-efficacy percepts and behavioral outcomes. Therefore, the research question asks: *How does context influence users' perceptions of self-efficacy and behavioral outcomes of persuasive systems use?*

Method and approach: A longitudinal field study was selected as research design to address the research question, since the hypotheses are closely bound to the specificities of the use context, which requires studying users in a natural setting, and the processual nature of the research model calls for a longitudinal design. The study relies on long-term (i.e., > 6 months) wearable users as participants who self-report weekly on multiple measures regarding their wearable use for seven weeks. The weekly surveys include questionnaires with regard to the last feature used, the internal and internal context in the specific situation, self-efficacy in the respective situation (i.e., situational self-efficacy), and users' compliance behavior. The scales used for the constructs of situational self-efficacy and compliance behavior are self-developed and yielded good to excellent results for their internal validity as indicated in the pilot study.

For the full study, around 140 participants were recruited who met the primary inclusion criteria. However, dropout rates were high and left data from seventy-six participants for analysis. Also, some of these participants did not take all of the weekly surveys. Hence, due to the limited sample size, data analysis using partial least squares structural equation modeling as planned was not possible and an additional round of data collection is needed to reach an adequate sample size of 100 to 150 (Wolf et al., 2013).

Results: The results of the pilot study, which was conducted over the full seven-week observation period but relied on a limited sample of ten participants indicated support for the hypotheses. To test the overall effect of the context on situational self-efficacy, a random-effects panel linear regression model was used, suggesting a negative effect of context on situational self-efficacy ($\beta = -0.417$; $p = 0.016$). Moreover, a panel logit model was used to test the effect of situational self-efficacy on compliance behavior, indicating a positive effect ($\beta = 1.192$; $p = 0.013$) and a good model fit (Adjusted R2 = 0.392).

Theoretical contribution: The contributions to be expected from the full study are twofold. First, the findings will contribute to persuasive systems research by clarifying users' behavior change processes and the factors that may restrict or support users' self-efficacy to change, highlighting non-linearity of the processes of acquiring novel behaviors. Second, the findings will extend the self-efficacy literature by demonstrating the situational and transient nature of users' self-efficacy perceptions contrasting established generalized constructs of self-efficacy that assume stability across contexts (cf. Chen et al., 2001).

4.5 Paper 5: "Affordances and Behavioral Outcomes of Wearable Activity Trackers"

Motivation: Wearable activity trackers are attributed great potential with regard to overcoming major health risks. While some studies from medical and nutritional sciences find positive effects (e.g., Barwais et al., 2013; Finkelstein et al., 2016), others do not find any effects at all (e.g., Slootmaker et al., 2009; West et al., 2016) or discover that the effects are not sustained long-term (e.g., Jakicic et al., 2016). Since IS research has primarily been looking into the use of wearable activity trackers (e.g., Kari et al., 2016), the question '*how do wearable activity trackers lead to behavioral change?*' is unanswered. This study aims to answer this question by applying the technology affordance lens (cf. Volkoff & Strong, 2013), which is well-suited to investigate the complex intertwining between the users' goal-configuration, the action possibilities provided by the material properties of wearable activity trackers and the resulting behavioral outcomes. The technology affordance lens allows for building the bridge between the IT artifact and its outcomes and for explaining why the same IT artifact leads to different outcomes with different users.

Method and approach: Twenty-five narrative interviews with Switzerland-based continuous long-term users of wearable activity trackers by Fitbit and Apple were conducted. This approach allowed for capturing individual user experiences in a chronological picture. To analyze the data, the five-step process suggested by Leidner et al. (2018) was applied which helps to extract and link material features, user goals, technology use, actualized affordances, and behavioral outcomes.

Results: The results yielded various affordances of wearable activity trackers that had been actualized by users, which fall into two broad categories: learning affordances and behavior-focused affordances. These actualized affordances can lead up to substantial changes in behaviors (i.e., behavior change), more simple adjustments to comply with technology cues (i.e., compliance change), and remaining with the status quo. These strands were found to differ depending on users' goals and characteristics, which were classified as different user types with distinct sets of goals and use motivations (i.e., problem-solvers, performers, dataficionados, and self-observers).

Theoretical contribution: The study makes several contributions to wearable activity tracker research. First, the results underline the importance of user goals and classes of affordances, which explain differences in affordance actualization and behavioral outcomes among users. Thus, possible explanations for the ambiguous results of effectiveness-studies of wearable activity trackers are offered. Second, by showing that behavioral outcomes can take various nuances, researchers are suggested to design studies allowing for more differentiation regarding outcomes. Last, five key propositions related to the role of user types and classes of affordances actualized by users are derived.

4.6 Paper 6: "The Generative Mechanisms Behind Technology-Enabled Changes in Health Behavior"

Motivation: Studies on the outcomes of wearable use paint a rather ambiguous picture: while IS scholars suggest that wearables can indeed support and empower users in performing beneficial behaviors, it is also noted that they can exert negative influences on users' cognitive-affective and behavioral responses (cf. de Moya & Pallud, 2020; James et al., 2019b; Rieder et al., 2020a). This study therefore seeks to reveal the underlying mechanisms that drive users' interaction processes with wearables and the subsequent behavioral and cognitive outcomes by answering the following research question: *How and why does wearable use enable behavioral and cognitive outcomes?* The objective to understand why some wearable users show behavioral change, while others do not, demands for pursuing an approach, that enables identifying the underlying mechanisms. Therefore, the study employs a critical realist stance, which has the concept of generative mechanisms—a form of causal powers—at heart (Bhaskar, 2008).

Method and approach: The narrative interview technique was used as method of inquiry, following the guidelines by Küsters (2009). Thirty long-term wearable users based in Switzerland were interviewed. To reveal the generative mechanisms driving individuals' use processes and outcomes related to wearables, Bhaskar's (2008) original four-step process of "explanation formation" (pp. 125) was followed: (1) 'decomposition' to resolve a complex event into its components to make causal analysis possible; (2) 'redescription' of the complex event (i.e., wearable use history) in order to enable theorizing about the present generative mechanisms; (3) 'retrodiction' involving backward chaining from consequent to antecedent events, and inductively and creatively conjecturing causal explanations that may have produced the respective events; (4) 'elimination' to extract the generative mechanism(s) that *actually* caused the complex event from a set of candidate mechanisms. Elimination was conducted on two levels: within and across individual interviews.

Results: The critical realist data analysis revealed seven different generative mechanisms driving wearable use as well as users' related cognitive and behavioral outcomes. Generative mechanisms with a tendency to change behaviors include self-improvement, self-determination, and confirmation. These three mechanisms not only have the power to impel the continuous use of wearables, but they also drive users' alteration of their offline health behaviors. Mechanisms with a tendency to generate purely cognitive outcomes are self-documentation, self-knowledge, exploration, and social relatedness. While individuals' use patterns driven by these four generative mechanisms are continuous, too, the mechanisms do not drive changes in users' physical behaviors. Instead, we found various cognitive outcomes related to these generative mechanisms, like learning, entertainment, and feelings of social belonging.

Theoretical contribution: First, the study extends the literature on persuasive technology by presenting a differentiated picture with respect to the technology's potential to improve users' health behaviors. Second, by identifying generative mechanisms that result in either behavioral or cognitive outcomes, an explanation for why previous research has observed ambiguous outcomes of wearable use is provided. Third, the study provides scholars with a step-by-step approach to identify generative mechanisms at the individual level.

4.7 Paper 7: "Design Blueprint for an Adaptive Persuasive Health System"

Motivation: While persuasive health systems were shown to be effective in boosting physical activity and caloric expenditure, and reducing sedentary periods (Barwais et al., 2013), their capacity to improve other outcomes, such as, physical activity levels and body weight as well as to induce long-term changes was questioned (e.g., Slootmaker et al., 2009; West et al., 2016; Jakicic et al., 2016). Moreover, IS studies outlined the potential detrimental effects on emotions (de Moya & Pallud, 2020), self-efficacy perceptions, and cue-adherence (Rieder et al., 2020a). Given the discrepancy between expectations and the realities of persuasive technologies, this research aims to provide theoretical insight on how to develop a persuasive system that is effective in evoking health behavior change. The following research questions are addressed: RQ1: *What are the fundamental challenges of persuasive systems for health behavior change and what design requirements can be derived from these challenges?* RQ2: *What design principles and design features to guide the development of a persuasive health system are suitable to address these design requirements?*

Method and approach: The paper applies the design science research methodology (Hevner et al., 2004; March & Smith, 1995), following the process by Peffers et al. (2007) and the specific approach used by Meth et al. (2015). Based on an intensive literature review to identify the problem and challenges, a set of preliminary requirements for the artifact was developed. In the object definition phase, design principles were derived drawing on the body of knowledge and established theories. In the same phase, the generic design features needed to be able to realize the principles were identified. As part of the design features, tools with the objective to facilitate the implementation of the design features were elaborated. The abstract design blueprint was then demonstrated to and evaluated with different actors in the health ecosystem using semi-structured interviews, using the approach proposed by Hevner et al. (2004) to contrast black box (i.e., functional) with white box (i.e., structural) perspectives for evaluating an artifact. Based on the feedback the artifact was refined.

Results: Based on the challenges identified in the empirical literature on persuasive health systems, the following design requirements (DR) were derived: persuasive health systems should anticipate users' unique experiences of interaction (DR1); should be tailored to users' individual needs (DR2); should follow and support users' psychological processes (DR3); should support users in overcoming contextual constraints (DR4); and should incorporate digital components that are effective in evoking behavioral change (DR5). These requirements shall be addressed through three design principles (DP) building on the self-determination theory (Deci & Ryan, 2008) and the transtheoretical model of health behavior change (Prochaska & Velicer, 1997). The design principles are: the system and the persuasion strategies are personalized to users' individual needs (DP1: personalization); adapt to users' stage-specific needs (DP2: adaptivity); are designed for sustainable long-term change (DP3: sustainability). The principles can be realized through two classes of features, containing three individual features each. First, features to determine the optimal configuration for the individual user are needed. Second, to capture the dynamics of health behavior change, the individual configuration must be adjusted to appeal to changes in the context and users' progression through the behavior change process.

Theoretical contribution: Within the field of health, the artifact may be used in various contexts, such as, physical activity, nutrition, sports and exercise, mental well-being, and disease self-management, to improve an even greater variety of health-related behaviors; it thereby serves a broad and generic problem class. Moreover, being a design blueprint for IS to achieve a specific category of outcomes in the users' domain (i.e., sustainable health behavior change), the artifact presented is highly mutable (cf. Gregor & Jones, 2007), i.e., independent of the kinds of physical and digital components of an IS, the underlying types of data, and specific technological advancements. Last, combining the two core concepts, self-determination theory and transtheoretical model of health behavior change, is novel with regard to persuasive health systems. While researchers have called for addressing personalization (e.g., Kaptein et al., 2015; Chatterjee et al., 2018), adaptivity to changing context and users' progression through the change process, has been overlooked.

5 Discussion

The research papers outlined in the previous sections served the purpose of closing the existing gaps in research on persuasive technology for health promotion. In particular, the goals were to gain an understanding of post-adoptive use processes, to explain the occurrence of adverse experiences and their effects on users, to explain the outcomes of persuasive technology use, and to generate design knowledge to develop persuasive technologies to achieve long-term changes in health-promoting behaviors. For this, I used different research approaches. I empirically investigated post-adoptive use and outcomes of persuasive technology use applying qualitative and quantitative research methods, and I followed the design science research paradigm to generate design knowledge.

In the following subsections, I present the key findings of this dissertation, the theoretical contributions, and implications for research and practice.

5.1 Main Findings

The main findings of this dissertation relate to seven topics. First, I find that persuasive technology use habits are formed in recurring processes of emerging triggers, actions, and rewards and that are driven by two underlying mechanisms, i.e., pre-existing habits and the technology. While use habits driven by pre-existing habits become entangled in existing behavioral sequences (e.g., sequences related to exercise habits) bit by bit, use habits driven by the technology are exogenously imposed on users and introduced to their lives leading to the formation of new sequences.

Second, I underscore that persuasive technology use can give rise to adverse experiences that emerge as stressors, and cognitive-affective and behavioral strains (i.e., technostress). In attempts to mitigate such experiences, users employ various coping strategies, some of which are benign and healthful. However, I also identified malicious and harmful coping strategies that users employ to deal with adverse experiences that may be detrimental to technology interaction patterns (e.g., mental distancing) but more importantly to users' physical and mental health (e.g., obsessive behavior).

Third, my research suggests that persuasive technology provides users with information that is taken into consideration when forming perceptions of self-efficacy. Thereby, persuasive technologies can, to a certain extent, steer users' behaviors. However, the processing of this information into perceptions of self-efficacy is imperfect, as the momentary configuration of users' internal and external contexts shape users' self-efficacy and the following behavior. While context primarily acts as a limiting factor to users' self-efficacy perceptions, internal context (e.g., self-motivation, habits) can also neutralize other negative context. Thereby, I show that users' self-efficacy perceptions and behavioral reactions are not stable, but transient for health promoting behaviors, because contexts are subject to change.

Fourth, I highlight that users actualize two classes of affordances (i.e., potentials for action) when using persuasive technologies: learning and behavior-focused affordances. Both classes of affordances are associated with distinctive outcome tendencies. While learning affordances (e.g., understanding one's sleep quality) rarely involve direct impulses on users' health behaviors, behavior-focused affordances (e.g., reviewing own activity) are closely linked to changes in health behaviors.

Fifth, my results shed light at a variety of outcomes that can follow persuasive technology use. Besides behavioral categories, like compliance with system cues and fundamental changes to behaviors and routines, cognitive-affective categories play a central role. Cognitive-affective outcomes may include such effects as entertainment, approval and validation, learning, and social belonging.

Sixth, I identify seven generative mechanisms that drive different phenomena of post-adoptive use (e.g., specific use of features, and data, use patterns, on-off-relationships) and the subsequent outcomes (i.e., cognitive-affective and behavioral). Thereby, I explain why behavior change does occur with some users but not with others and why behavior change is not a predetermined outcome of persuasive technology use, not even for long-term users.

Finally, I postulate that persuasive technologies that aim to effectively induce long-term changes in health promoting behaviors have to fulfill three design principles: personalization (i.e., be tailored to the individual and his or her motivation, goals, and needs), adaptivity (i.e., accompany users along the process of change), and sustainability (i.e., adjust to the dynamics of change and be designed for long-term interaction).

5.2 Theoretical Contributions

The theoretical contribution of this dissertation with regard to persuasive technology research is threefold. First, I extend the body of knowledge on post-adoptive persuasive technology use by explaining how habits are formed with respect to persuasive technology use. While prior research had a rather technology-centric stance on the drivers of continuous use and habit formation (e.g., Matt et al., 2019; Pinder et al., 2015), my research demonstrates the importance of users' pre-existing habits. Moreover, I highlight the underresearched dark side of persuasive technology use (cf. Schmidt-Kraepelin et al., 2019) in untangling the processes and drivers of the occurrence of adverse experiences and investigate users' coping behaviors in the face of adversity.

Second, I contribute to research on the outcomes of persuasive technology use. I corroborate the findings by prior research that highlight the dualistic effects of persuasive technology use on users' cognitive-affective categories (e.g., de Moya and Pallud, 2020; James et al., 2019b) and show that also behavioral outcomes are subject to dualism. Going one step further, I unveil the drivers (i.e., generative mechanisms) of the phenomena related to persuasive technology use, specifically the differential outcomes, and take a more nuanced view on these outcomes (cf. James et al. 2019a; Ogbanufe and Gerhart, 2020). Concluding that context, users' interpretation and actualization of affordances, and the generative mechanisms that are acting at the substratum are key drivers of specific patterns of interaction and outcome tendencies, I broaden the view of prior research that has taken a more technology- or personality-centric approach to explain outcomes (e.g., Rockmann et al., 2019; James et al., 2019a; James et al., 2019b) or—like most studies in medical and nutritional research—leave the black box of outcomes unopened.

Third, by presenting design knowledge with regard to persuasive technologies for health promotion, I contribute to design research in this area. My design artifact is solidly based on empirical problems, uses established justificatory knowledge, is suitable to solve problems from a broad class, is mutable, and testable through the presented propositions. Besides following the established principle of personalization (e.g., Chatterjee et al., 2018; Kaptein et al., 2015), my artifact attends to the processual nature of behavior change (cf. Prochaska & Velicer, 1997) by realizing stage-specific guidance through dynamic adaptation, which represents a novel facet of persuasive technologies.

Moreover, the dissertation makes several specific contributions to the domains in which the individual research projects are set. First, by untangling the isolated and interdependent effects of context, I contribute to context research (cf. Avgerou, 2019; Bamberger, 2008). I demonstrate that context significantly informs and determines users' cognitive and behavioral categories, thereby adding to the line of research which assigns context critical importance rather than treating it like a negligible construct or nuisance to IS use. Moreover, I indicate that context can interact in different ways producing different (i.e., compounded or neutralizing) effects. Second, I contribute to the self-efficacy literature in indicating the variability of the construct with regard to health-related behaviors, presenting a juxtaposition to established generalized approaches to self-efficacy (e.g. Chen et al., 2001). Last, I provide a methodological contribution by providing a step-by-step approach for critical realist data analysis at the individual level. While prior IS research has provided guidance for the identification of generative mechanisms at the organizational resp. macro level (cf. Wynn and Williams, 2012; Bygstad et al., 2016), extracting individual-level generative mechanisms requires a different approach.

5.3 Implications for Research

The findings of this dissertation have various implications for research. First, researchers should assign greater importance to pre-existing habits as drivers in users' habit formation processes. In prior research, their effect is generally underestimated. While pre-existing habits can support and facilitate the formation of new habits, they can also hinder them. Second, I demonstrate the role of context in influencing users' health-related behaviors both, positively and negatively. Cross-sectional studies may benefit from additionally including context-related constructs since they may offer insights into the reasons behind distortion in study results. Third, researchers from different disciplines should acknowledge the differences in the nature of outcomes from persuasive technology use. When assessing the success or effectiveness of a persuasive technology, researchers have traditionally built on variables that can reflect the changes in participants' behaviors. However cognitive outcome categories (e.g., learning, awareness, well-being) are rarely included even though they might be just as important. Fourth, the reasoning behind the generative mechanisms identified in this dissertation that drive the phenomena of post-adoptive persuasive technology use and its outcomes with may provide a basis for reconsidering the findings of and sampling strategies used in cross-sectional studies. Since most of these studies sampled participants based on cross-sectional criteria (i.e. age group, specific health condition), it is likely that multiple different generative mechanisms were present with the participants. Since use and outcomes are a product of the relational processes between what drives users and technological properties (Bygstad et al., 2016), it is unlikely that the same outcome will emerge for a group of users that are all driven by different mechanisms and actualize different affordances of the technology.

Moreover, I provide three practical tools scholars may use in research projects. First, I suggest a situationally variable construct for self-efficacy and develop a three-item-measurement scale for users' situational perceptions of their self-efficacy. Researchers assessing self-efficacy perceptions related to health behaviors may utilize this scale to obtain more differentiated insights on individuals' momentary states. Second, researchers intending to extract generative mechanisms at the individual level may follow my procedure for critical realist data analysis. Third, my design blueprint and the proposed features and tools may assist researchers in building research-grade persuasive technologies for use in health interventions.

5.4 Implications for Practice

This dissertation has multiple practical implications with respect to the design of persuasive technologies. When intending to build a persuasive technology for health promotion from scratch, designers may draw on the design blueprint proposed in this dissertation. Allowing for personalization and dynamic adaptation of the system configuration and offering useful tools, amongst others, a matrix to facilitate user profiling and a comprehensive catalog of persuasion strategies to pick from, the design blueprint may also be of use to designers who seek to adapt existing persuasive technologies for health promotion. Besides the design blueprint, the following implications for practice can be derived from the findings.

First, given the role of pre-existing habits to impel the formation of use habits, designers should give them more pronounced consideration. For example, when requiring users to reveal personal information (e.g., goals, weight, activity level) at the initial set up of the system, information regarding pre-existing sporting or other activity habits may be collected that can then be taken into account when proposing schedules for activities.

Second, designers should anticipate the possibility of adverse experiences and malicious coping strategies. As outlined above, such coping strategies can be harmful for both, technology interaction (e.g., users might decide to discontinue the use of a specific feature) and users' physical and mental health (e.g., obsessive tracking, feelings of guilt and pressure), so designers should incorporate features to mitigate such effects. Such features could include, for example, introducing off-time for users with obsessive checking habits or allowing for breaks to ease the stress for users who feel under pressure.

Third, demonstrating the volatility of users' behavioral responses due to contextual changes, persuasive technologies should repeatedly persuade users to perform a behavior. Users who have performed the requested behaviors multiple times may due to newly emerged constraints not feel confident to do the behavior. Therefore, persuasion is not only needed to initiate a behavior in the early stages of use, but also in later stages, to counteract negative context.

Fourth, when building a technology, it is important to consider users' interpretation and actualization of the affordances of the technology, not only the affordances that were intended by designers. On the one hand, it must be ensured that users understand how to use a technology and obtain outcomes from it. On the other hand, when planning on creating an impact on users' offline behaviors, the technology must afford such a behavioral impact (and not only learning affordances).

Moreover, the findings of this dissertation have important implications for the communication strategies and evaluation approaches used by providers of persuasive technologies. System providers should be aware that generative mechanisms drive users' adoption decisions, technology interactions, and outcomes. Hence, having a clear communication strategy with regard to technical affordances may help users to pick the system that satisfies their individual needs generated by the mechanisms running in the background. For instance, lifestyle users driven by a confirmation mechanism with an interest in tracking activities in their daily lives are likely to be overwhelmed by a sophisticated sports tracking device. Conversely, a mountaineer driven by a self-improvement mechanism training for their next alpinistic endeavor will need differentiated insights into their training parameters that cannot be offered by lifestyle devices. System providers should ensure a communication strategy that allows users to make the right choice based on the generative mechanism they are driven by and the technical affordances of the system in question. With respect to evaluating a system's effectiveness, providers should take into consideration two aspects: First, interaction with the technology does not equal effectiveness and impact of a system. Hence, usage data alone is not appropriate to evaluate effectiveness. Second, given the differentiated view on outcomes of persuasive technology use, evaluation approaches should further attend to non-behavioral measures that may reflect the success of a persuasive technology with regard to cognitive-affective outcomes (e.g., learning, awareness, well-being).

6 Limitations and Further Research

The dissertation is subject to some limitations that give rise to avenues for further research. Set in the field of health promotion and relying on wearable self-tracking devices as the research context for the empirical studies, the generalizability of the findings to other fields of application of persuasive technology may be limited. Further research may assess the applicability of the findings in other settings and fields in which persuasive technologies may purposefully influence individual behavior, for example, environmentally friendly behavior, adherence to hygiene standards, traffic safety, and retirement planning. Moreover, the empirical studies relied on participants from Switzerland or the German-speaking areas of Europe. Hence, future research should assess whether the results prevail in different cultural contexts. Last, further research may implement the design artifact proposed as part of this dissertation and rigorously evaluate an expository instantiation for its effectiveness.

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8 Appendix

Table. Overview of Related Work

Labels: A = adoption; PA = post-adoptive use; OC = outcomes; D = design

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Chuah et al. (2016)	✓				Perception of smartwatch as fashion accessory or technology; ease of use; usefulness	Adoption intention, attitude toward smartwatch	Technology acceptance model	Perception of smartwatch as technology: usefulness is the more important factor in forming attitudes and intentions; Perception as fashion accessory: visibility is more important
Fox and Connolly (2018)	✓				Privacy concerns; ability to adopt	M-health technology adoption intention	Social cognitive theory; protection motivation theory	Older adults' ability and intentions to adopt m-health
Kari et al. (2016)	✓				User expectations, behavioral intentions, experiences	Factors influencing users' adoption or rejection decisions	UTAUT2	Concepts from UTAUT2 supported; additionally, (dis-) confirmation of expectations regarding self-improvement properties affected rejection resp. adoption
Kim and Park (2019)	✓				Coolness (consisting of utility, attractiveness, subcultural appeal, originality)	Positive user attitude; intention to use	--	Attractiveness and originality affect both, utilitarian and hedonic values, and increase user attitude and intention to use

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Lee and Lee (2018)	✓				interpersonal influence, personal innovativeness, self-efficacy, attitudes towards fitness tracker, health interests, perceived expensive-ness; aware-ness of wearables	Adoption intention	--	Individuals who are aware of wearable fitness trackers have stronger intentions to adopt; positive associations of personal innovativeness and health interests and adoption intentions
Lim and Noh (2017)	✓				Gain-framed vs. loss-framed messages	Exercise self-efficacy; intentions to use fitness app; outcome expectations of exercise	Prospect theory; self-efficacy theory	Gain-framed messages are more effective in evoking users to take up the use of a fitness app than loss-framed messages
Liu et al. (2014)	✓				Loyalty rewards	Enrollment; initial and ongoing engagement	--	Loyalty rewards increase individuals' likelihood (by factor 27.9) to join an e-health program; in later stages, loyalty rewards are no longer effective
Lunney et al. (2016)	✓				Perceived usefulness, perceived ease of use, perceived subjective norm, attitude towards fitness trackers	Fitness tracker use, expected health benefits	Technology acceptance model; theory of planned behavior	All established relationships supported.

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Pfeiffer et al. (2016)	✓				Factors from theoretical perspectives	Intention to use	Technology acceptance model; UTAUT; UTAUT2	Acceptance model for wearable self-tracking devices with support for most established determinants.
Attig and Franke (2020)		✓			Wearable activity tracker use patterns	Reasons for abandonment	--	List of reasons: motivation loss, perceived measurement issues, design and discomfort, obsessive tracking, privacy concerns
Benbunan-Fich (2019)		✓			Reports of use experience	Affordances and failures of affordances	Affordance theory; activity theory	Mediator role of reduced wearable devices; sources of failures
Gimpel et al. (2013)		✓			Self-tracking motivations and behaviors	Classes of self-tracking motivations; time spent tracking	--	5 motivations: (1) self-entertainment, (2) self-association, (3) self-design, (4) self-discipline, (5) self-healing; cumulative effect of different motivations increases tracking activity
Matt et al. (2019)		✓			Wearable use experiences	Continuous use	UTAUT2, Health Information Technology Acceptance Model, Health Information Privacy Concerns Model	Determinants of continuous use from 3 categories: (1) perceived benefits, (2) perceived deficiencies, (3) perceived privacy

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Mettler and Wulf (2019)		✓			Affordances; constraints	Shared mental models	Affordance theory	Mental models and user types present in wearable use in occupational settings
Nasci-mento et al. (2018)		✓			Habit, perceived enjoyment, perceived usefulness, confirmation, perceived usability, satisfaction	Continuance intention	IS continuance model	Habit, perceived usability, and perceived enjoyment increase the predictive power by 15%; dominance of utilitarian values since enjoyment has only indirect effect on continuance intentions
Prasopou-lou (2017)		✓			Individual experience of adoption and use	Entangling of technology in life	Enchanted materialism	Memoir of use experience
Rockmann (2019)		✓			Motivational affordances: (1) self-monitoring, (2) rewards, (3) social recognition	Competence satisfaction; competence thwarting; continuance intention	Self-determination theory	Competence need thwarting affects fitness app continuance intentions mainly for beginners; dualistic influence of rewards and social recognition affordances
Rockmann et al. (2018)		✓			Perceived usefulness; perceived enjoyment; system-unrelated emotions	Continuance intention	Reference literature on emotions	Evidence for emotional carry-over effects: continuance intentions are influenced by affective states unrelated to technology use

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Sjöklint et al. (2015)		✓			Use experiences of wearables	Users' perceptions of the wearable, reactions to goals, coping strategies	Heuristics and biases	Wearables direct awareness to hidden personal aspects and thereby motivate users to pursue behavioral changes; when conflicts between users' rational and emotional reactions to personal data arise, they use different coping tactics (e.g., disregard, procrastination, selective attention, neglect)
Bhattacharya et al. (2018)			✓		Pivotal experiences by users (previously) undergoing health behavior change	Factors leading to pivotal experiences; role of technology in pivotal experiences	Transtheoretical model of health behavior change	4 factors lead to pivotal experiences; technology reinforced experiences, their immediacy, and helped identify the next steps to be taken, but did not cause them
Brickwood et al. (2019)			✓		Review of 26 randomized controlled trials on wearable-mediated preventative health interventions	Meta-analysis of treatment effects	--	Overall, significant increase in daily step count, moderate and vigorous physical activity, energy expenditure; non-significant decrease in sedentary behavior
De Moya and Pallud (2020)			✓		Use of self-quantification	Users empowerment and disempowerment	Panopticon metaphor	Empowering and disempowering influences of wearable use on dimensions power, body, knowledge, and space

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
James et al. (2019a)		✓	✓		Exercise goal (intrinsic, extrinsic)	Feature set use; subjective vitality	Goal content theory	Likelihood of using specific feature sets based on exercise goals; increased subjective vitality only associated with intrinsic goals
James et al. (2019b)		✓	✓		Exercise motivation	Feature set use; subjective vitality	Organismic integration theory	6 user subtypes with distinct feature sets and different wellness outcomes; positive wellness outcomes for autonomously motivated and amotivated users
Ogbanufe and Gerhart (2020)			✓		Perceived risks and benefits of use	IT identity; deep use; individual performance	IT identity theory	IT identity mediates the effect between wearable use and deep use behaviors, and individual performance
Chatterjee et al. (2018)				✓	Persuasive messages	Evaluated system to support diabetes prevention	Fogg behavior model	Artifacts: persuasive messages, sensor system, predictive analytics tool
Kaptein et al. (2015)				✓	--	Persuasive system tailored to individual users resp. their traits	Reference principles from social psychology	Design requirements for persuasive systems that allow for personalization through explicit and implicit profiling
Michie et al. (2013)				✓	Behavior change techniques in health interventions	Taxonomy of behavior change techniques	--	Taxonomy of 93 individual behavior change techniques from 16 hierarchically clustered categories

Reference	*Process insight*				*Variables studied*	*Nature of outcome*	*Theoretical perspectives*	*Primary contributions*
	A	*PA*	*OC*	*D*				
Oinas-Kukkonen and Harjumaa (2009)				✓	--	Guiding framework for persuasive systems design	--	Process model for persuasive systems design; design principles in 4 categories: (1) primary task support, (2) dialogue support, (3) system credibility support, (4) social support
Pinder et al. (2018)				✓	Synthesis of established behavior change and habit theories	Conclusive framework and description of 11 habit-forming strategies	Dual process theory; modern habit theory; goal setting theory	"Habit Alteration Framework"
Yassaee et al. (2019)				✓	Analysis of tensions occurring during wearable use in occupational settings	3 classes of tensions: (1) value tensions (privacy vs. wellbeing); (2) action tensions (work vs. leisure activities); (3) role tensions (leisure vs. work roles); design principles to cope with tensions	Various theories and frameworks as justificatory knowledge	Design principles to cope with the tensions: social fairness, social presence, social response, interruption management, structural role redefinition, personal role redefinition

Research Paper 1:
"Understanding the Habitual Use of Wearable Activity Trackers"

Authors: Rieder, A., Lehrer, C., and Jung, R.

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Understanding the Habitual Use of Wearable Activity Trackers

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Abstract

Given the large discrepancy between rates at which wearable activity trackers (WATs) are initially adopted and their continued use, the question concerning how sustainable use emerges arises. While IS research has found habit an important driver of sustained use, the mechanisms of habit formation have been left unexplored. To address this research gap, we conducted narrative interviews to investigate the habit-formation mechanisms behind the use of WATs. We identified two drivers of habitual WAT use and constructed five narratives that provide insights into the habit-formation processes of WAT users and possible interrupting factors. Our results provide a valuable basis for both theory and practice in explaining how sustained WAT use develops.

Keywords: Wearable, Habit, Habit Formation, Sustained Use, Continuance.

1 Introduction

The growth in the wearable industry continues as increasing sales figures and numbers of adopters of wearable activity trackers (WATs) buoy the technology's success [11, 27]. However, abandonment rates for the devices are striking [11]. A study by Endeavour Partners reported that users' minimum attrition rate is as high as 30 percent within the first six months [18]. However, sustained use is a prerequisite for inducing long-term changes in health behavior, which is most WAT devices' key value proposition. Information systems (IS) research has identified habit as a key driver of continuous IS use [e.g., 20, 3], but most of its studies of habit and post-adoption phenomena are quantitative in nature and focus on the relationship between habit and factors like continuance, leaving the underlying mechanisms of habitual IS use unexplained. Research that has investigated WATs [e.g., 1, 12] has provided only a few insights into users' perspectives and experiences. Clarifying how habitual use patterns emerge in the context of WATs and post-adoption phenomena would help in designing WATs in a way that supports users' sustainable behaviors and habits. Against this background, our research question asks, *What are the underlying mechanisms of habitual WAT use?*

We used a narrative interview technique in qualitative interviews with ten habitual WAT users to gain a longitudinal insight into the users' experiences with the devices. Eyal's (2014) IS habit formation model, which is grounded in psychology and neuroscience research, provided a valuable theoretical lens through which to investigate the cognitive and behavioral processes of habitual WATs users and the factors that can interrupt habitual use.

The paper proceeds as follows. First, we discuss the theoretical background on wearables, the role of habit in IS, and the mechanisms behind habit formation. Then we present our methodology and the results of our analysis. Finally, we conclude with a discussion of our results and limitations and a proposal for further research.

2 Theoretical Background

2.1 Wearable Activity Trackers

"Wearables" refers to any electronic computing device worn on the body and that uses sensor technology so users can track their personal activities and vital parameters [32, 29]. Even though a wide range of devices (e.g., wristbands, glasses, clothing) fall under the umbrella term of wearables, we focus on wearable devices that track physical activity: WATs. Wearable devices that are designed only to track other health-related parameters, such as fertility, blood pressure, or blood glucose levels, do not fall into the category that we investigate in this paper. WATs, which usually take the form of bracelets and watches, are the most popular category of the wearables market [11]. These devices allow users to self-optimize by providing them with insights into their physical performance through self-tracking of such parameters as steps, sleep, sports activities, and food consumption [29, 10]. Users can usually interact with WATs directly over the device's screen or via mobile applications, which are typically accessible using a smartphone.

Because of the possible positive effects of WATs on personal health, the healthcare sector places considerable value on their potential. The intended behavioral outcomes of wearable use, such as increased activity levels and conscious nutrition, are key preventive measures that can improve public health and reduce strain on healthcare providers and insurers [10]. However, this promising outlook is dampened by the large discrepancy between adoption rates and sustained use. Findings from the US show that, despite adoption rates higher than 20 percent in 2014 and estimated adoption rates higher than 35 percent by 2020, attrition rates are as high as 30 percent within the first six months of use [18, 27]. Consequently, many WAT users do not reach the phase of sustained long-term use, which is a better indicator than mere adoption with which to assess the success of WATs [4]. Research has identified several issues that lead to discontinuance, including short battery life, inaccurate sensors, privacy concerns, insufficient data, and irrelevant information provided to users [6, 7, 27]. Some authors have also suggested that the design of WATs insufficiently incorporates findings from behavioral theory [21, 6, 7].

To date, research on wearables has predominantly followed a quantitative approach to examine the effectiveness of using WATs in health behavior interventions [e.g., 12], and only a small fraction of articles has focused on the experiential side of WATs and the qualitative analysis of the user's perspective [e.g., 2, 13, 24]. The majority of articles has addressed only the adoption process, so we lack qualitative experience-centric research that explores sustained WAT use in the post-adoption phase.

2.2 Habit in Information Systems Research

Research on continued IS use in the post-adoption phase has consistently highlighted the importance of habit as a key predictor of continued IS use [20, 3, 14, 22, 19]. Habit can be defined as the automatic or unthinking performance of specific behavioral sequences, such as the use of an IS artifact, to obtain a certain goal in response to environmental cues [20, 3]. Automation occurs through the processes of repetition and learning.

Studies that have investigated the effect of habit on continued IS use have shown two primary influences: a direct positive influence on IS continuance, continuance intention and satisfaction [3], and an indirect suppressing effect that moderates the relationship between continuance intention and actual continuance [20]. Bhattacherjee and Lin's (2015) findings also supported this link, corroborating the notion that automatic behavior reduces the need for intention. Limayem et al. (2007) identified four antecedents of habits in IS use: frequency of the behavior, satisfactory outcome, a stable context, and the use of various features of the IS in question (comprehensiveness of use). Building on these findings, a handful of studies have investigated continued IS use and the role of habit in specific use contexts, including participation in online communities [14], online gambling [22], mobile location-based services [19], and quitting Facebook use [31].

Whereas the extant research on habit in IS use has involved variance theory, predicting the relationships between antecedents and outcomes, Kim (2009) offered a process view on IS continuance and the influence of habit. Drawing on a process model from cognitive psychology that outlines how memory is formed, Kim sheds light on the process that drives post-adoption behaviors. However, the model does not provide a detailed explanation of the process of habit formation itself.

In summary, the extant IS research assigns habit an important role in predicting IS continuance, but it has yet yielded only a few attempts to untangle the mechanisms and processes behind habit formation. Therefore, we turn to Eyal (2014), who developed a process model to explain habit formation with digital products and services.

2.3 Mechanisms of IS Habit Formation

Process of IS Habit Formation. Eyal's (2014) process model indicates that IS habit formation takes place in four-step cycles: trigger, action, variable reward, and investment (Figure 1). This view is in line with the definition of habit from social psychology, which understands habit as automated dispositions to respond to specific cues to obtain certain goals or end-states [25, 33]. Responses are learned sequences of acts, memorized through a process of repetition that have led to satisfactory outcomes in the past [25]. Habit formation takes place when a trigger—that is, an environmental cue—instructs users in a more or less explicit way about what action to take next [33, 25]. If users are sufficiently motivated and capable of performing the behavior, they will execute the action [9]. The action always takes place in anticipation of a reward, which users expect to receive upon completion of the action [25]. After multiple repetitions, users start building associative links between the trigger and the action and between the action and the reward, which lead them to repeatedly and effortlessly perform the behavior when they are confronted with a similar context [28]. Users also typically "invest" in a specific technology by putting something of value into the system (e.g., effort, time, skill acquisitions) [8]. Along with the processes of associative learning, such investments increase the likelihood that users will repeatedly pass through the process [26]. Repeating this process with high frequency is critical to habit formation [17, 25].

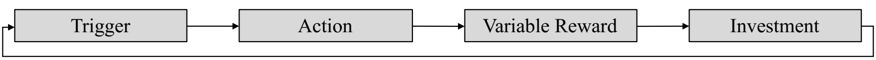

Figure 1. IS habit formation model (based on [8])

Trigger. A trigger can be understood as an "actuator of behavior" [8, p. 7], the first step in the habit cycle. Triggers are goal-related in so far as they cause individuals to desire a certain reward that they expect on execution of a specific behavior [33, 8]. The literature differentiates between external and internal triggers [9, 33] such that external triggers are stimuli sent out by the technology that tells the user what behavior to perform next (e.g., a push notification that reminds the user to take a specific number of steps every hour), while internal triggers do not require a sensory stimulus but are firmly installed in users' minds and automatically activated as certain thoughts, emotions, or routines come up. Examples of internal triggers are feelings of boredom or hunger, certain weekdays, and preceding actions. Having laced up one's running shoes could serve as an internal, routine-based trigger for users to activate their WATs' sports monitoring function.

Action. Action refers to the behavior performed in response to the trigger and in anticipation of the reward [33]. Performing the action requires the user to be sufficiently motivated and able to do so [9]. Pursuing the goals or end states that result from performing the action can include seeking to achieve a positive goal but also avoiding a negative one. Ability, that is, the ease with which a user can perform an action, also influences the likelihood that the action will occur. Ability involves the user's personal capabilities and skillset, as well as contextual factors like time restrictions and the physical environment [25]. In the context of WATs, an action could include making the missing number of steps to fulfill the daily goal. Thereby, the user's motivation to execute this action could, for example, be negatively influenced by the weather, while restrictions to the user's ability could include not having sufficient time or being temporarily incapacitated due to an injury.

Variable Reward. The successful completion of the action is followed by a variable reward, a "positive reinforcer" of behavior [28, p. 89; 33]. With repeated encounters with a similar situational context, associative links between the context and response that have yielded a specific reward are established [33, 25]. Thus, what drives the user to comply with the trigger is not the reward itself but its anticipation, which causes the emission of neurotransmitters in the human brain [28]. The reward should be variable in so far as it provides the user with some degree of novelty [8]. Rewards can take a variety of forms, including social rewards, rewards that fulfill the human desire to acquire resources and information, and rewards that have intrinsic benefits. Eyal (2014) highlighted the importance of the fit among the reasons an individual uses a product, his or her internal triggers and motivations, and the reward. Related to WATs, rewards could, for example, include receiving badges, seeing an upward tendency in performance, or improvements in wellbeing.

Investment. Users' investments in a product or service (e.g., time, data, effort, social capital) influence the value they assign to it [cf. 26]. In the case of technology and software, such investments can enhance the users' experience and, thus, increase the likelihood of re-engagement [8]. Stores of value with technology can take the form of data, followers, acquired skill, content, or reputation. In the context of WATs, investments could comprise a personal training history or a network of friends and followers.

3 Methodology

Since empirical evidence of the process through which habitual WAT use is formed is scarce, we employed an inductive, qualitative approach using narrative interviews, following established principles [16, 5], to capture individual users' experiences and a longitudinal picture of the individual's use history. In this interview technique, the interviewee recalls and gives an account of a past event [16]. Typically, the interview's organization and structure are left to the interviewee, and the interviewer does not intervene with the narrative until the interviewee has recognizably ended his or her recitation. Thus, this interview technique can help to overcome common biases like social desirability, as well as patterns of interaction in the interview, issues related to the wording and placement of questions, and topics and terminology brought in by the interviewer [16].

3.1 Data Collection

We interviewed ten WAT users who were based in Switzerland, which, with a 7.6 percent market penetration in wearable devices in 2017, is one of the most advanced markets for wearables in Europe [30]. In line with the narrative interview technique, we used no interview guideline [16]; instead, we used a pre-formulated initial stimulus to ignite the interviewees' narratives: *"I would like you to tell me the story of your activity tracker. This means from the moment you got it, until today."* We did not intervene until the interviewees had recognizably finished their narratives. Then we took up topics the interviewees had mentioned in their initial narratives to trigger additional accounts. All of the interviews were held in person, and interviewees were ensured anonymity and confidentiality in the statements they made during the interview. The narratives' duration (ranging from 24 to 68 minutes, with an average length of 42 minutes) and level of elaboration varied widely. We recorded and transcribed the interviews verbatim to ensure rigorous and transparent analysis of the resulting data. Interviews and transcriptions were done in the participants' native language, either German or Swiss German dialect, and were processed by native German speakers. The quotations presented in this paper were translated into English.

As we sought depth over breadth of information, a sample of ten participants was adequate to gain rich insights into personal use histories and to identify various habit formation processes. We followed a criterion-based sampling strategy [23], taking the respondents' gender, age, and duration of use into account. Although generalizability is not a primary objective in qualitative research, we tried to distribute interviewees evenly across both genders and to cover a broad age range. Our sample consists of four females and six males whose ages range from 18 to 58 years (M=33.5), and it includes both students and professionals (Table 1). The sample slightly over-represents younger people, but younger people tend to adopt WATs more frequently than older people do [30]. We also chose continuous WAT users (i.e., those who used their devices past the trial phase) who had used their WATs for at least six months, although a few had used them for several years. The use frequency varied across interviewees and largely depended on the motivation for use. Most interviewees used the device every day and even at night, while others only wore it only when they engaged in sports. Most of them used their WATs to track their daily activity, support their sports performance, and improve their health. Some reported using the devices to explore the novel technology out of curiosity. The four functionalities used frequently and long-term by more than three participants were step-counting (nine out of ten participants), sports-activity monitoring (6 participants), competition (5 participants), and heart-rate feedback (3 participants). Fewer than three participants used nutrition tracking and sleep tracking habitually, which others used mainly on a trial basis.

Table 3. Sample characteristics

Alias	*Age*	*Gender*	*Occupation*	*Total use duration*	*# WATs used*
INT1	25	F	Student	> 24 months	2
INT2	24	F	Student	6 - 12 months	1
INT3	57	F	Project manager	12 - 24 months	2
INT4	58	M	Consultant	> 24 months	4
INT5	41	M	Entrepreneur	12 - 24 months	2
INT6	41	M	Entrepreneur	6 - 12 months	1
INT7	25	M	Student	6 - 12 months	1
INT8	20	F	Student	6 - 12 months	1
INT9	18	M	Student	12 - 24 months	2
INT10	26	M	Bartender	6 - 12 months	1

3.2 Data Analysis

The data analysis process broadly followed Chatman's (1978) recommendations. In the first step, we used narrative coding to decompose the narrative into its elements so we could extract the kernel sequence of events. According to Chatman (1978), the story of a narrative consists of *events* and *existents*. Events can be understood as changes of state that are driven by *actions* executed by significant agents (e.g., *"In the beginning, I measured my heart rate relatively consistently" (INT4*);*"This was when I actually stood up and started walking through the apartment"* (INT1)) and *happenings* that occur but are not directly influenced by the agents (e.g., *"This fitness tracker brought to my attention what I was eating and how often I was exercising"* (INT2); *"The problem was that it just wasn't working most of the time. Then there was something wrong with the software, then this, then that"* (INT3)). Existents, on the other hand, are descriptive elements of the story that are constituted of *characters*, which are animate or inanimate agents that advance the plot (e.g., *"I wasn't really a sports enthusiast"* (INT9); *"My fitness tracker is a first-generation Apple Watch"* (INT5); *"The platform has more analytical functionalities, where my running coach could see my progress"* (INT4)) and the *setting*, which is the space in which the characters exist and act (e.g., *"I had two, three colleagues in school who had this too"* (INT9); *"During the semester break we took off the device when we had to study because we wouldn't even make 1,000 steps per day"* (INT1)).

We differentiated between kernel and satellite sequences of events. Kernel events are actions and happenings that advance the plot and are central to the participants' narrative. For example, kernel events were identified if the participants gave an in-depth and lengthy recounting of their use history of a key WAT functionality. Satellite events are not central to the plot, so omitting them does not alter the story. For example, satellite events include when participants mention a WAT functionality only briefly or tell how they used it only on a trial basis.

In the second step, in which we focused on the kernel sequences of events, we identified the WAT functionalities that the participants used habitually: sports-activity monitoring, heart-rate feedback, step-counting, and competitions. Indicators of habitual use patterns were long duration of use, regular use, and signs of automaticity (e.g., when a user mentioned that he or she always and unthinkingly performed certain actions). For those functionalities, we identified the underlying drivers of habitual use. While our research process was exploratory, we were sensitized by the concepts of Eyal's (2014) IS habit-formation model and used the model to identify how the steps of trigger, action, reward and investment were represented in the data along the narratives. The IS habit-formation model proved to be an appropriate theoretical lens, as the interviewees went through steps of the process when they used their devices' various functionalities.

4 Results

Our analysis revealed two drivers of habitual WAT use identifiable across narratives. On the one hand, habitual WAT use was driven by users' offline habits performed independently of WAT use, as it was the case for the functionalities sports activity monitoring and heart rate feedback. On the other hand, the technology itself fostered habitual WAT use by sending out triggers, as with step counting and competitions. Each of the following subchapters covers one of the two motors. The first subchapter illustrates habitual WAT use driven by offline habits by presenting the composed narratives for the functionalities sport-activity monitoring and heart-rate feedback. The narratives in the second subchapter on the motor habitual WAT use driven by the device, are related to the functionalities step reminders, activity statistics, and competitions. The narratives presented below follow the logic of the IS habit formation model, comprising the three impelling elements *trigger*, *action*, *reward*, as well as potential *interrupting factors* to habitual use found in the data. We purposely left out the *investment* element of the model, as we did not find any explicit mentions in relation to specific WAT functionalities.

4.1 Habitual WAT Use Driven by Offline Habits

4.1.1 Habitual Use of Sport Activity Monitoring

Sport activity monitoring allows users to track their exercise (mainly running) using performance indicators like distance, pace, and blood oxygen consumption. A characteristic of this functionality is the need to switch it on and off to monitor the activity while it is being performed. The interviewees who habitually used sport activity monitoring typically had already established a sports habit—usually running—or wanted to develop one before they adopted a WAT. Most had a clear focus on sports and intended to support their sporting goals using a WAT or were interested in monitoring and the data as such.

> *It's a Christmas gift that I asked for because I went running regularly. I basically used the tracker for running. I also wore it during leisure time and at work, but I mainly used the functionalities for running, like to measure the distance I had run. It also monitored the heart rate, which was useful sometimes, and especially the time per kilometer, which was very important to me. I w0anted to see the progress I made. (INT10)*

Sport activity monitoring was in all cases cued by a pre-existing (offline) sports habit, which can be classified as an internal trigger. Intending to or preparing to engage in sports would automatically trigger the participants' subsequent action of switching on the sports tracking mode. In addition, several interviewees engaged in information retrieval after the sports training sessions and even processed the information further by, for example, sharing it with their social networks or feeding it into other data analytics platforms.

> *When I bought the Suunto, I started trying out the apps. I found that very exciting. There are lots of interfaces through which you can export data. My main platform is Strava, which allows me to see my activities. For example, I went skiing, and you can see where I took photos. I'm sure there are some people who would call this profile neurosis, but I think it's fun. (INT4)*

Using sport activity monitoring brought the interviewees multiple kinds of rewards that were all based on the technology. The interviewees often mentioned that the statistics and history motivated them and allowed them to monitor their progress and path toward reaching their goals, which had a confirming effect. Moreover, quantification and visualization of the sports training sessions were considered rewarding in themselves because they led to insights into novel parameters. Monitoring the training sessions also gave the interviewees a sense of achievement because parameters like calories burned, time trained, and distance covered were made transparent. Sports activity monitoring also rewarded them with social recognition when they shared their achievements through social network sites and received positive responses. In addition, spending time with the monitoring data was perceived as entertaining, as they could, for example, keep track of their routes on Google Earth and add the photos they had taken during the training.

> *Of course, it is great at the beginning, when you're proud or when you do your ten kilometers for the first time and pass your limits for the first time, or when you do your first trail run. Of course, you do want to share this and document all of it. (INT5)*

The most common cause for interruptions of the habitual use of sport activity monitoring was loss of the reward. Besides not being able to look at the statistics because of technical problems or a general lack of interest in seeing one's progress, interviewees described how the documentation lost its novelty and excitement after a time. Other such interrupting factors were changes in underlying offline habits that resulted in loss of the trigger and broken devices.

> *For me, it was the case that it didn't particularly motivate me anymore. It was more like you've been outside for an hour in fresh air and had a good time, so documentation wasn't that important to me anymore because I realized I felt good. You end up doing it regularly – when you move from compulsion to enjoyment. That makes the difference. (INT5)*

4.1.2 Habitual Use of Heart-Rate Feedback

Heart-rate feedback, which provides users with close to real-time information about their heart rate, is constantly running in the background. This functionality was mainly used habitually by interviewees who also reported strong, established sports habits or wanted to develop them before adopting a WAT. Using heart-rate feedback served specific goals: improvements in distance and pace or high calorie burn.

> *The story of how I came across the fitness tracker was that I started to go running on a regular basis, like two to three times a week, and I had to measure my heart rate because it was not supposed to exceed 160. I think my personal trainer was afraid I would have a heart attack. (INT5)*

A pre-existing (offline) sports habit serves as an internal trigger, so engaging in a habitual activity like running or doing cardio exercise automatically set the cycle in motion.

> *I also used the heart-rate monitor during sports. I always checked it; for example, when I went running, I would eventually have to make a cardio peak and then I always checked whether it was over 160. (INT2)*

The interviewees report two subsequent actions in the case of heart-rate monitoring: constant interaction with the device during the activity to check the heart rate and immediate adjustment (e.g., breathing, pace) when the heart rate deviated from the target.

> *I tried to keep a lower pulse on longer distances and not go at full intensity. I also tried to slow down a bit when my pulse was at 160 or so. The tracker was really useful for when you want to improve your running performance. Sometimes, even when you don't have the impression you're going so fast, you take a look at your pulse and the pace and you say, "Oh, 170 is maybe a bit too high for a flat route—should probably slow down." (INT10)*

The rewards interviewees got from using heart-rate monitoring were not usually delivered by the technology but were internal. Interviewees reported rewards that were personal in nature, such as feeling good, improving, being able to run longer in a healthier way, and getting to know their bodies.

However, through repetition and learning, interviewees felt they had acquired a subjective feeling for their bodies and heart rates, which obviated the need to use the digital heart-rate feedback provided by WATs. Changes in underlying habits that resulted in loss of the trigger, and broken devices are other factors that interrupted the habitual use of the heart-rate feedback.

Once you've reached a certain level–this was the case with me after some three months, and after half a year it got really easy–where you can run for an hour plus, you've learned to deal with it and you also feel for yourself which pulse is good for you, then you don't need the technical support anymore to guide you. As you get to know your body better, the device becomes less informative. (INT5)

4.2 Habitual WAT Use Driven by the Device

4.2.1 Habitual Use of Step Reminders

The step-counter of a WAT is always running in the background, recording each movement that is sensed as a step. Most WATs come with pre-set hourly and daily step goals or let users specify goals themselves. External triggers in the form of push notifications on the WAT screen or the user's smart phone drove the habitual use of the step-counting functionality for our interviewees. The devices reminded users to move if they were to achieve their hourly activity goals or informed them of how many steps were left to reach their daily step goals. Such push notifications triggered the interviewees to interact with their WATs and to engage in offline actions—that is, to take the number of steps that were necessary to reach a certain goal.

I always got something five or ten minutes before the hour saying, "Hey, 300 steps left for the hourly goal" or so. It was vibrating, and then you realized, "Oh, I've been sitting around for an hour looking at the computer. I'll get up and go to the toilet or somewhere else just to walk a few meters." You're always reminded when an hour passes and another hour passes, and you haven't moved at all. (INT7)

Interviewees reported various rewards upon executing the triggered behavior. Complying with the cue usually left them with the feeling of being energized and more fit during their daily activities. Moreover, as making hourly step goals also added to the overall step count, they felt that compliance contributed to overall goal achievement. With WATs that were using a different technique like a punishment logic with a red bar that appeared on screen after a certain amount of sedentary time, executing the action was perceived as a relief.

The more bars you had, the longer it took to get rid of them, so if you had one bar, you could cross your apartment two or three times before it eventually disappeared. But when you had five bars, this meant you would have to move for five or ten minutes to get rid of all of them. Yes, the red bar really annoyed me. (INT8)

The most common interruption to the habitual use of step reminders the interviewees mentioned was the loss of the trigger if users stopped wearing the WAT regularly. Even though the interviewees intended to maintain their activity levels, they reported being unaware of their hourly number of steps and so were not cued to move.

> *I only stand up when I really have to. If I am not made aware of it, I don't think, "Oh, I haven't gotten up for three-quarters of an hour straight." (INT9)*

4.2.2 Habitual Use of Activity Statistics

WATs provided the interviewees with a wide variety of statistics and historical data about their physical activity, graphically represented in dashboards that were accessible via smartphone app. Unlike using step reminders, using these functionalities requires the user to access and retrieve information actively.

> *I was curious to see how many steps I take and how this changes over the course of the week–how this changes based on whether you're doing sports or are just at university. Even if I did not reach my step goal each day, I just concentrated on the weekly average and made sure that I got a daily average of 10,000 steps per day, and if I succeeded in that, I didn't care too much when I had a day on which I had fewer steps and another one with more. Then it was kind of balanced. (INT1)*

For some functionalities, the triggers are external, but they take a passive form, as they remind users of the goals they have set and to interact with the technology when it catches their attention. For example, merely seeing the wristband on one's wrist or seeing the WAT app on the screen of a smartphone app can serve as a trigger.

Triggered actions can be comprised of only interaction with software components or can also include execution of an offline behavior. Interviewees regularly checked their numbers of steps, consulted their statistics and histories, and looked into the progress they had made toward reaching their goals. However, most interviewees used their WATs' functionalities not only by interacting with them but also by adapting their offline behavior based on their progress toward their goals. Most participants engaged in extra activity if they had not reached their step goal yet.

> *When you're looking at your device and you see that you have half the steps that you normally do, it's a bit shocking and you think you'll have to do something about it. (INT7)*

Interviewees received a variety of rewards from the technology for executing the actions it triggered, including a sense of achievement, confirmation from an upward trend over the use history, and avoidance of "punishment" when the interviewee's goal was to prevent a downward movement in data. Engaging in offline behavior in response to the activity history also added to interviewees' well-being and their perceptions of their fitness, as it kept them active and moving.

When you went running, you quickly got 15,000, 16,000 steps, and that was great. I had days on which I had 25,000 steps–that made me proud. And then it also told you the calories, and then you saw you really burned a lot. (INT3)

For some users, learning effects decreased the interviewees' perceptions of rewards and their excitement from using the activity history functionality for a period of time.

It eventually loses its novelty value or you eventually know and get a feeling for how many steps you've walked. (INT6)

The interviewees' ability to perform the offline behavior was restrained in some cases when they faced changing schedules or lost awareness of the number of steps they had taken after discontinuing use of their WATs.

I know that I don't do a lot during the exam period, and I think that I can't because I have tons of other stuff to do. But when you have it in black and white that you have 1,000 steps over the whole day, you just don't wear the WAT at all to silence your conscience. (INT1)

4.2.3 Habitual Use of Competitions

WATs offer users the opportunity to compete against other users through a social network. The functionality, which is based on step-counting, lets users initiate or accept competitions and provides them with reports in the form of rankings or reminders entailing the status of the competition. Competing against other WAT users was rarely the interviewees' initial motivation to use a WAT; instead, they learned about the function when they adopted their devices and tried it out with their friends. The strength of the habit of using competitions was affected by one's social network's motivation and involvement.

In the beginning, it was fun to see how many steps I take, but then two or three colleagues at school had the device too and there was the possibility to engage in challenges against each other. I eventually started walking home from school just to win the challenge. (INT9)

Engagement in competitions was triggered external to the device when the interviewees were invited to compete against other users or initiated the competition themselves. To participate in a competition, interviewees had to take the first action of initiating or accepting an invitation. Further actions included checking the competition status and the rankings in the social network. The interviewees also often engaged in an offline behavior like taking more steps to win a competition.

> *It motivated me. I purposely took the stairs or, when I had to take the subway for one stop, I walked instead because I desperately wanted to beat my boyfriend. (INT2)*

Rewards for participating in a competition were usually delivered by the technology. Interviewees drew social recognition from competitions, as others got to see how active and fit they were and offered admiration. Interviewees also received confirmation through winning a competition that confirmed that they were better or more active and sporty than their competitors, which served as a form of reward. Besides being entertaining, competitions also supported interviewees' fitness by prompting them to take even more steps.

> *I believe this is what motivates people most–comparing themselves to others. You look up on Freeletics or Linkedin what all the other people are doing and you think, "Ah, shit, I totally don't have my life under control," and then you do something about it. (INT2)*

The reason for ending the habit was usually that interviewees lost interest in the rewards. Similar to step-counting, some interviewees lost interest in the function after the excitement and novelty value had vanished and rewards had become predictable.

> *At some point, after all these competitions were nothing special anymore, it just wasn't an advantage to me anymore. (INT2)*

Other problems had to do with restricted social networks and frequently losing competitions, both of which negatively affected the rewards connected with the behavior.

> *With the one colleague I used it with, I didn't have any chance. Even when I thought I had done lots of steps, like 40,000 or so a day, he ended up getting 60,000. Then I thought I'd have to stop this, as it started annoying me. (INT1)*

5 Discussion

This study investigates the mechanisms behind habitual WAT use. Based on narrative interviews, we identified two distinctive drivers of habitual WAT use and constructed five narratives that provide insights into WAT users' habit-formation processes and possible interrupting factors. The two drivers of habitual WAT use are pre-existing offline habits and the device itself. When offline habits drive WAT use, WAT use is embedded into existing behavioral sequences that have become habitual prior to WAT adoption. When use habits are driven by the device, users are incited to learn and perform new behaviors.

Our research contributes to the literature on habit and wearables and has implications for theory and practice. First, we contribute to the IS literature on habit [e.g., 20, 3] by unveiling the process by which use habits are formed in the context of WATs. Two drivers of habitual WAT use are pre-existing offline habits and the technology itself, but only one of the two drivers tends to be in effect with a particular user—that is, users either habitually used their WATs in response to an offline habit (INT3, 4, 5, 10) or were driven by the technology (INT1, 6, 7, 8, 9), rather than being motivated by both drivers (INT2). Moreover, taking into consideration Limayem et al.'s (2007) research, which provided insights into antecedent conditions of IS habit, our findings indicate that comprehensiveness of use is not a substantial driver of habit in the WAT context or for our sample. On the contrary, we observed a tendency toward long-term use and stronger use habits the more users were focused on only a few functionalities of the WAT. Wide adoption of WAT features was often associated with trial usage or weak habits.

Second, we contribute to research on wearables by offering insights into the experiential side of WATs, particularly by providing information about habit-formation processes and habitual use of WATs. Unlike to several other kinds of IS, WAT use cannot be conceptualized simply as interaction with the device's software components, as WATs aim to induce offline behavior, and the performance of such behavior constitutes a qualified form of WAT use. Our findings suggest that a much of what leads to interruption of sustained WAT use resides with the user, although the perspective of current WAT research predominantly allocates interrupting factors to the technological sphere.

Our research has several implications for theory and practice. First, our research suggests that it is reasonable to conceptualize habitual WAT use along its functionalities because users develop use habits for some functionalities, but not for others. Second, Eyal's (2014) IS habit-formation model is useful in explaining IS habits on a fine-grained level, as we found evidence for the stages of the model in our data. Therefore, IS researchers could apply the model to examine similar IS habit-formation processes. Third, our research offers producers clarity about the habit-formation processes that are related to WAT use and about potential interrupting factors. Building on such information, WATs designers can design them in a way that supports particular stages of the habit-formation process and that anticipates and counteracts the interrupting factors that are obstacles to long-term WAT use. Fourth, as habitual WAT use is driven in part by pre-existing offline habits, producers must shift their focus away from technology-driven behaviors to consider users' existing behavioral patterns and habits.

6 Limitations and Further Research

The present research is subject to some limitations. Because this research is qualitative, we limited the number of interviewees we used for analysis, so we may not have heard all variations of use cases in the WAT context or have covered all functionalities equally.

Future research may consider interviewing users with other use cases and contexts. Although the narrative interview technique is especially valuable when it comes to exploring longitudinal, process-like issues with highly individual character, some themes could be under-represented in the data, which could be why we found no evidence of the investment element in our data. While interviewees mentioned investment-related aspects of WAT use on a general level, such as appreciating the historic data or having gained specific use skills, we were unable to relate them to specific functionalities. Future research could verify this finding and investigate the role of investment in the habit-formation process with WATs. Moreover, habits always underlie automated cognitive processes that users do not necessarily consciously perceive. Therefore, when we relied on the interviewees' memories, we had to use interpretive proxies to identify such processes. However, also other forms of qualitative studies, as well as quantitative studies, address this particular limitation, so future research could use other research methods (e.g., mining WAT use data) to triangulate and establish reliability. Finally, future research could go a step farther to look into behavior changes that result from sustained WAT use and assess how WATs are keeping up with their goal of inducing behavior changes in their users.

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Research Paper 2:
"Technostress from Persuasion: Wearable Users' Stressors, Strains, and Coping"

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Technostress from Persuasion: Wearable Users' Stressors, Strains, and Coping

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Abstract

The use of persuasive technologies to improve users' personal health outcomes are becoming increasingly pervasive in the health context. While early research on persuasive technologies highlighted the technology's individual and societal potential, recent empirical evidence has hinted about the adverse effects of their use. However, little is known about the causes of, experiences with, and coping reactions to these adverse effects. To fill this gap, we conduct an exploratory study of wearable technologies' adverse effects on users based on twenty-five narrative interviews. Employing a technostress lens, we find two distinct patterns–control stress and validation stress–that show that users experience these adverse effects by revolving through a circular process of technostress and relying on various mechanisms to cope with it. We describe contributions to the literature and implications for research and practice.

Keywords: Technostress, persuasive technology, wearable, stress, coping, dark side.

1 Introduction

Persuasive technologies are socio-technical information systems (IS) that are designed to change users' attitudes or behaviors (Fogg 2003). They are prevalent in the health context, where they are used to induce their users to engage in healthful behaviors to improve personal health outcomes through persuasion (Lehto and Oinas-Kukkonen 2015). In their most prominent forms—fitness apps and wearable self-tracking devices—they have found their way into mainstream users' lives. Given their behavior-changing properties, they can help to improve personal and public health outcomes, thereby reducing strain on the healthcare system (Gimpel et al. 2013). However, striking attrition rates and pessimistic study results on the technologies' effectiveness have put their capacity to induce long-term changes in users' health behaviors into question (Jakicic et al. 2016; Ledger and McCaffrey 2014; West et al. 2016).

Recent studies in IS have broached the subject of adverse effects related to the use of persuasive health technologies and noted the importance of looking into the adverse cognitive and behavioral effects of using them (Schmidt-Kraepelin et al. 2019). These studies have found that users' motivation (Schmidt-Kraepelin et al. 2019), intention to continue (Rockmann 2019), achievement of exercise goals (Liu et al. 2016), perceived self-efficacy, compliance with system requests (Rieder et al. 2019b), and wellness outcomes (e.g., James et al. 2019) may be negatively affected by these technologies. While these studies have provided evidence of adverse effects related to persuasive technology use, more insights into the causes of adverse effects, the patterns of use they cause, and users' reactions to cope they give rise to are needed so providers can develop appropriate countermeasures that allow these technologies to live up to their potential to change behavior. Our research question asks: *Why do users encounter adverse effects when using persuasive technology?*

To address this research question, we conducted an exploratory study using narrative interviews with twenty-five users of wearables, one of the most popular kinds of persuasive technology. Our data analysis was guided by the technostress lens (Ayyagari et al. 2011; Tarafdar et al. 2017) which IS researchers have used extensively to investigate a variety of dark-side phenomena (e.g., Maier 2015; Salo et al. 2019). In providing a process view of users' experiences of adverse effects of technology use, it is a suitable perspective through which to view the phenomenon. Our findings indicate that the technostress experienced by users–who describe repeatedly passing through the perception stressors that arise from technology use and the resulting strains–is related to two drivers of wearable use: controlling one's behavior and obtaining normative approval. We find two distinct patterns of technostress (i.e., stressors, strains, and coping mechanisms) for these drivers: control stress and validation stress.

Our study expands the body of literature on the adverse effects of persuasive technology used in the health context by explaining how and why users experience technostress. Our study also contributes to technostress research by applying the technostress perspective to individual IS with a focus on changing users' health behaviors. We offer important implications for practice–particularly for designers of persuasive technologies and health interventions–that can help to improve persuasive technologies' ability to mitigate their negative effects on users and leverage their full potential to change behavior.

The paper is structured as follows. Section 2 discusses the theoretical background, particularly the concepts of persuasive technology and technostress. Section 3 describes our methodological approach. Section 4 presents the results of our study, followed by a discussion in section 5 and limitations and avenues for future research in section 6.

2 Theoretical Background

2.1 Persuasive Technology

Persuasive technologies are computing systems, devices, and applications that are designed to change users' attitudes or behaviors in a predetermined way (Fogg 2003). To do so, persuasive technologies use techniques that induce changes in behavior (Oinas-Kukkonen 2013), such as self-monitoring, rewards and threats, goal-setting, and social comparison (Mercer et al. 2016). Such persuasive elements may range from simple user-interface-design elements to more holistic features.

Persuasive technologies are prevalent in the health context (Lehto and Oinas-Kukkonen 2015); they have been employed and studied in the domains of mental health (e.g., Kuonanoja et al. 2015) and physical health, influencing physical exercise (Khalil and Abdallah 2013; Lim and Noh 2017), food consumption (Ronen and Te'eni 2013), and smoking cessation (Myneni et al. 2016). With the emergence of mobile apps, wearable devices, and the novel kinds of interactions they afford (e.g., automated tracking and analysis of daily activity, sports, nutrition, or sleep), these systems have become the ubiquitous platforms for the delivery of health-related interventions (Oinas-Kukkonen 2013). Central to health-persuasive technologies is that they not only allow users to track health-related parameters but also help them to alter offline behaviors to promote healthful outcomes (Ogbanufe and Gerhart 2020). For instance, they support users in abandoning detrimental behaviors like smoking or in adopting health-promoting ones like regular exercise.

IS studies have investigated the individual and societal effects of persuasive health technologies. For example, James et al. (2019) demonstrated a positive effect of wearable use on subjective vitality if internal motivators were present with users. Another qualitative study on wearable technology indicated that wearables may reinforce existing health and exercise habits and give rise to new ones (Rieder et al. 2019a). In an evaluation of a persuasive system for diabetes self-management, Chatterjee et al. (2018) noted promising effects on health-related indicators (e.g., steps per day, weight, blood glucose, and idle time). Some of the trials in the medical and nutritional sciences performed to determine the effectiveness of persuasive technologies on health-related outcomes have had promising results regarding their capacity to increase users' physical activity and reduce sedentary periods and caloric intake, while other studies have presented a more pessimistic outlook questioning these technologies' ability to induce behavioral change given the absence of significant effects on such parameters as physical activity, aerobic fitness, body weight, and body composition (e.g., Slootmaker et al. 2009; West et al. 2016). Moreover, a trial with a two-year observation period found that the beneficial effects observed in the short term were usually not sustained in the long term (Jakicic et al. 2016). (For a comprehensive review, see Brickwood et al. (2019).)

IS researchers have also begun to raise concerns about persuasive technologies in light of increasing evidence of adverse effects related to users' cognitions and behaviors. In a review of IS literature on the negative effects of gamification in health behavior change support systems, Schmidt-Kraepelin et al. (2019) identified five categories of unintended side effects: adverse motivational effects, informational noise, reduced integrity of exercise, demoralization, and overstepping boundaries. Focusing on the acceptance phase of use, Matt et al. (2019) noted that users of wearables reported that limited reliability, perceived functional constraints, and limited support were deficiencies that may hamper their ability to transition to continuous use of wearable devices. Liu et al. (2016) investigated the negative effects of social norms-based mobile health interventions and found that messages containing references to social norms were related to lower rates of achievement of physical activity goals, perhaps because of a reduction in users' intrinsic motivation that arose from the social-norm cue or because social-norms cues predominantly attract weak users who then set unattainable goals. In an effort to explain users' continuance intentions, Rockmann (2019) found that the motivational affordances of fitness apps may negatively affect users' perceptions of their own competence. Specifically, rewards and social recognition features may put pressure on users and lead them to seek goal attainment for non-autonomous motives. Similarly, Rieder et al.'s (2019b) exploratory study on the behavioral effects of wearable use revealed that adverse effects (i.e., low self-efficacy and non-adherence to wearable requests) were traceable to wearable use's occurring in unfavorable personal or contextual circumstances. James et al. (2019) investigated users' selection of feature sets and the psychological well-being outcomes that result from the use of fitness technology and found that using fitness technologies yielded positive outcomes for the well-being of both highly self-determined and completely unmotivated users, while less self-determined users whose motivations for exercising were external saw a negative relationship between technology use and psychological well-being. Mettler and Wulf (2019) elaborated on the constraints wearable users perceived, but since they were studied in an occupational setting, most constraints related to the adverse effects of being forced by an employer to use a wearable device in an organizational context, so the findings are transferable to the individual IS context to only a limited extent. De Moya and Pallud (2020) offered one of the few studies to investigate the ambivalent influences of wearable use. They showed that, in imposing constant surveillance (through the wearable) on themselves, wearables exerted empowering as well as disempowering influences on users. Disempowering influences included such effects as users' accepting the wearables' standards and goals without reflection, which diminished their self-determination, and patterns of mental punishment and self-presentational issues (De Moya and Pallud 2020).

However, despite providing empirical evidence of the complex and multi-layered nature of the phenomenon of persuasive technology use, most of these studies did not investigate its adverse effects. A more comprehensive understanding of users' experiences of the adverse effects of persuasive technology use is needed to leverage the technologies full potential to change behavior. Specifically, we need to identify the processes along which users experience adverse effects, that is, what causes them, the patterns of use and adversity they generate, and the coping reactions to which they give rise. To address this need, we draw on the technostress perspective, which provides a process view of users' experience of adverse effects (i.e., stress) when they use technology.

2.2 Technostress

Technostress describes the stress that individuals may experience from using technology (Ayyagari et al. 2011). As the psychological reference literature has indicated, stress occurs if individuals perceive the demands placed upon them by the environment as exceeding their coping capabilities and threatening their well-being (Cooper et al. 2001; Lazarus 1991). Therefore, "stress" refers to the overall transactional process in the course of which individuals encounter stressors—that is, events or properties of events that invoke individuals' psychological responses, referred to as strains.

Building on this tradition, IS scholars have conceptualized technostress as a process in which individuals evaluate technology's characteristics in terms of whether stressors are present that may give rise to strains (cf. Ayyagari et al. 2011; Tarafdar et al. 2017). Technology *characteristics* may encompass ease of use (Ayyagari 2011), reliability (Jiang et al. 2002), multipurpose functionality (Salo et al. 2018), and ubiquity (Tarafdar et al. 2017). These characteristics may then lead to individuals' perceptions of such technology *stressors* as overload, invasion, uncertainty, and complexity (e.g., Tarafdar et al. 2007; Maier et al. 2015; Barley et al. 2011). Technology characteristics and technology stressors are linked by the concept of primary appraisal, which refers to the individual's evaluation of the adverse situation (Tarafdar et al. 2017). This cognitive appraisal process is shaped by factors that reside with the individual, such as workload, digital literacy, involvement, and attitude toward IS, (e.g., Barber and Santuzzi 2015; Barley et al. 2011; Tarafdar and Ragu-Nathan 2010), which shape the magnitude of the perception of stressors. In response to the technology stressors, *strains* arise, which are adverse emotional, cognitive, and behavioral outcomes that manifest as, for example, decreased well-being, exhaustion, low productivity, poor performance, low commitment, and burnout (Maier et al. 2015; Ragu-Nathan et al. 2008; Salo et al. 2018). To mitigate the impact of technology strains, individuals may employ *coping* responses (Salo et al. 2018; Tarafdar et al. 2017) like adapting how they use the IS or disregarding some requirements (Salo et al. 2015; Stein et al. 2015).

Even though stress, including technostress, is related to both negative (e.g., distress) and positive (e.g., eustress) outcomes (cf. Lazarus 1966; Tarafdar et al. 2017), stress has primarily been applied in IS in investigations of dark side-phenomena.

IS research that has used the technostress concept has predominantly investigated organizational and workplace IS (e.g., Ayyagari et al. 2011; Chandra et al. 2019; Ragu-Nathan et al. 2008; Tarafdar et al. 2007; 2011; Turel and Ma 2019). Researchers have examined technostress experienced by employees in various industries (e.g., Shu et al. 2011) and job functions (e.g., Tarafdar et al. 2015), focusing on both the use of various work-related IT devices and their associated applications (e.g. Ayyagari et al. 2011) or the application of a particular IT device, such as a mobile phone (Hung et al. 2015). Studies on organizational and workplace IS have concluded that technostress may be due to stressors that are related to job characteristics and workplace relationships (Ayyagari et al. 2011). Related strains include reduced productivity, job dissatisfaction, and burnout (Ragu-Nathan et al. 2008; Srivastava et al. 2015; Tarafdar et al. 2007).

Recently, IS scholars have adopted the technostress lens to study phenomena related to individual and leisure use of IS (e.g., Lee et al. 2014; Luqman et al. 2017; Maier et al. 2015; Salo et al. 2017; 2018) to explain the adverse effects of smartphones and social networking sites and services (e.g., Brooks et al. 2017; Lee et al. 2014; Maier et al. 2015), so the technology stressors and strains these studies identified were related to users' private spheres and their leisure-time use of the technology, rather than occupational factors. For instance, Salo et al. (2017) identified two classes of strains from leisure-related technostress: the individual strains of concentration and sleep problems and the social strains of identity and social relationships.

Following Baskerville's (2011) notion of individual IS, we argue that the idiosyncratic needs, motives, and preferences that drive the use of such IS may shape the technostress process in ways that are distinct from those related to organizational IS use. For example, in terms of coping behaviors, users of individual IS may freely decide to discontinue using the IS, which might not be possible with IS at the workplace. As individual IS, persuasive systems in the personal health context may invoke a technostress process that differs from that observed in organizational contexts—particularly because persuasive systems intend to influence individuals' (offline) behaviors, which holds potential for inner conflict (cf. de Moya and Pallud 2020).

3 Method

Our research uses a technostress perspective to investigate the occurrence of adverse effects and their impact on users' cognitions and behaviors when they use persuasive technology. Since empirical evidence of the adverse effects of persuasive technology use is scarce, we used a qualitative approach to obtain in-depth personal descriptions of individuals' adverse experiences. As wearables are a prominent category of persuasive technology, we used them as our research context and conducted narrative interviews with twenty-five long-term users of commercially available wearable devices.

3.1 Research Context

With the development of wearables, a new category of health-related persuasive technologies has emerged. Wearables are electronic computing devices, worn on the body, that use sensor technology so users can track their personal activities and parameters like steps, sleep, sports activities, and food consumption (Benbunan-Fich 2019; Mettler and Wulf 2019). Our analysis focuses on devices that take the form of wristbands and watches and that track physical activity, which are also called wearable activity trackers–the most widely proliferated category of wearables (IDC 2018). Leading providers include Apple, Xiaomi, Fitbit, and Garmin (Statista 2019). Wearable devices that are limited to tracking other health-related parameters, such as fertility, blood pressure, or blood glucose levels, are not part of our investigation.

Through self-tracking, wearables enable users to gain insight into their physical performance. Interaction and reviewing the data is facilitated through the devices' screens or via accompanying software applications, which are typically accessible by a smartphone. Wearables are usually advertised to support users in improving health behaviors, so they incorporate various behavior-change techniques (Mercer et al. 2016; Ogbanufe and Gerhart 2020), rendering them persuasive technologies (Oinas-Kukkonen 2013). For example, by adding walks to daily schedules or by replacing existing eating habits with more healthful ones, users may form or alter their behavioral patterns.

Wearables may also help to reinforce desirable behaviors, and the provision of workout histories and statistics may help make exercise habits more appealing.

3.2 Data Collection

We follow a qualitative approach, conducting narrative interviews to capture in-depth descriptions of users' experiences of adverse effects while they use persuasive technologies (Küsters 2009; Myers 1997). In this kind of interview, the interviewee gives an account of a past event, using his or her own organization and structuring. Since the interviewer does not interrupt the narrative, the technique avoids common biases like social desirability, patterns of interaction in the interview, issues related to wording and placement of questions, and topics and terminology brought in by the interviewer (Küsters 2009). We consider the narrative interview a suitable technique with which to address our research question for several reasons. First, in asking the interviewees to reproduce past events and experiences, we obtain data in a narrative that has a largely sequential structure. We found that the sequential nature of data is particularly well-suited to obtaining insights into users' processes of use, adverse effects, and coping behaviors and to viewing the data that are conceptualized as a process, such as stress in general, and that is, in this case, specifically technostress (cf. Folkman and Moskowitz 2004; Salo et al. 2019). Second, because of the minimal interference from the interviewer, we discover only those adverse effects and consequences that the users actually experienced, without risking triggering answers or topics that are not related to the users' experience.

We interviewed twenty-five wearable users from Switzerland. One of the most advanced markets for wearables in Europe, wearables in Switzerland had a market penetration of 7.6 percent in 2018 (Statista 2018). Using purposive sampling (Miles and Huberman 1994), we followed pre-defined selection criteria to guide the participant-recruitment process. First, interviewees were required to be continuous intermediate- to long-term wearable users (i.e., past the trial phase) and to be using the device in private life. The focus on continuous users of wearables allowed us to identify the adverse effects that users encountered during their habitual use of the technology and the strategies they developed and behaviors they employed to cope with any adversity. The interviewees were not selected based on their activity levels, health status, wearable use habits, or previous negative experiences but were required only to be users of wearables for self-tracking purposes. Second, we tried to achieve maximum (socio-) demographic variation by including male and female students and professionals across a large age range. The interviewees were recruited from the authors' broader social networks through personal acquisition and with the help of social networking sites. The interviews were conducted between November 2019 and January 2020. All twenty-five interviews were held in person and recorded by a voice recorder. The interviewees were guaranteed anonymity.

In line with the narrative interview technique, no interview guideline was used (Küsters 2009; Myers 1997); instead, we used a pre-formulated stimulus to ignite the narratives and provide contextual information: *"Please tell me the story of your wearable, how it started until today."* After the interviewees had recognizably finished their narratives, we took up topics they had mentioned that were related to adverse effects they had encountered to encourage additional accounts of the situations, circumstances, and consequences of adverse effects. The duration and elaboration of the accounts varied across the interviews, which is reflected in the wide range in length, from 20 to 105 minutes (excluding preliminary talk and instructions). We transcribed the interviews verbatim so we could rigorously analyze the data. Interviews and transcriptions were done in German and processed by native German speakers, so the quotations presented here were given in German and then translated into English.

Full sample	#	*(%)*	**Devices used**[1]	#	*(%)*
N	25	*(100)*	Fitbit	12	*(48)*
Gender	#	*(%)*	Apple	10	*(40)*
Women	13	*(52)*	Garmin	10	*(40)*
Men	12	*(48)*	Other[2]	4	*(16)*
Occupation	#	*(%)*	**Use duration**	#	*(%)*
Students	9	*(36)*	6-12 months	4	*(16)*
Professionals	16	*(64)*	13-24 months	8	*(32)*
Age			> 24 months	13	*(52)*

Mean	Median	Min	Max
35.6	33	19	54

[1] Interviewees had used multiple devices of different brands.

[2] Other brands included devices by Samsung (1), Whoop (1), Suunto (1), and TomTom (1).

Table 1. Sample characteristics

Our interviewees, students and professionals who had been using their wearables continuously for at least eight months, were thirteen women and twelve men between nineteen and fifty-four years of age. While all of the students were studying in the fields of medicine, business, or psychology, the professionals were working in various industries (e.g., construction, education, health care, IT, transportation, financial services) and in various positions (e.g., assistants, managers, executives). Table 1 presents an overview of the study's participants. The frequency of the wearables' use varied across interviewees depending on the individuals' reasons for using them. Nineteen of the interviewees used the device in their everyday lives, thirteen wore it even at night, and six used it only during exercise. The interviews revealed a large number of detailed instantiations of adverse effects of wearable use and the associated cognitive and behavioral responses. Twenty-three of the interviewees recounted experiences with technostress, with no differences in this regard between users who used their wearables in their everyday lives vs. those who used them only while exercising. Gaining rich, in-depth narratives from twenty-five interviewees was deemed sufficient, as themes and instances began to repeat, signaling saturation (Corbin and Strauss 2008).

3.3 Data Analysis

In analyzing our interview data, we broadly followed the procedure for interpretive data analysis proposed by Corbin and Strauss (2008). First, we used open coding (cf. Corbin and Strauss 2008) to identify concepts related to instances of adverse effects from wearable use that were salient in the interview data. In this step, we kept our minds open to the emergence of new concepts from the data. This process resulted in more than 130 descriptive codes, which we then grouped into more abstract categories. To ensure the credibility of our data analysis (Wallendorf and Belk 1989), coding and categorization were done by the first and second authors in an iterative process involving frequent discussions. As an example of the categorization, the two following quotations were aggregated into the *over-transparency* category because the resulting strain was based on overwhelming transparency in both cases:

> *1) You can do some pretty good research for your age and weight and whether that is actually a good minimum heart rate, and you just can't escape it. (Male self-employed interviewee, age 36)*
> *2) When I was losing a competition, I would get this notification: "Your friend is ahead, catch up." (Female business student, age 26)*

Second, in a step similar to axial coding (Corbin and Strauss 2008), we organized the identified categories to represent the sequential pattern of events in the data. This step was sensitized by the technostress concept, as proposed by Ayyagari et al. (2011). The concept of technostress proved to be an appropriate lens, as we found that, in the course of using wearables and thereby being exposed to technology characteristics, users perceived an array of stressors that gave rise to strains in the emotional, cognitive, and behavioral domains. This step also entailed linking the coping behaviors users employed to the technostress sequences. On linking these sequences, we realized that the described processes were not self-contained, onetime occurrences for most users. Instead, the data indicated that users passed through the processes multiple times until they described acquiring coping behaviors. To ensure the confirmability of our analysis, the sequences and interpretations obtained in this step were presented to a researcher on the team who was not involved in collecting or analyzing the data for the researcher's judgment about the dependability and plausibility of the inferences and interpretations (Wallendorf and Belk 1989). The next quotation illustrates how the accounts in our data could be viewed through the technostress lens:

> *If my wearable tells me prior to a competition that my fitness level has decreased, it will affect how I approach the competition mentally. I am susceptible to this kind of information. If it says my fitness level has increased, I am much more motivated. Therefore, I decided to disbelieve this metric because I don't want it to influence me. Usually, these algorithms are not that smart, but rather simplistic. After all, there might be good reasons that your fitness level has dropped. Then the frustration is not that strong, so I can handle it. (Female nurse, age 52)*

While in this case the fitness-level metric describes a *technology characteristic*, the discrepancy with the feedback the interviewee wished for and the actual feedback is the *stressor*. This stressor caused *strains* in the user's cognitive domain in the form of frustration and lowered confidence. To circumvent the strains, the interviewee engaged in *coping behaviors*—in this case, rationalizing and distrusting the metric.

In the third step, we revisited the data for accounts of contextual information and drivers and motivations of use that could explain the observed patterns of technostress and coping behaviors. After linking the patterns of technostress, coping behaviors, and contextual information to obtain a holistic picture of the adverse effects the users encountered, we looked for the drivers of the technostress patterns in each interview. We found two drivers of wearable use—control and validation—that, in driving use, also evoked distinctive technostress patterns among wearable users and their coping behaviors in response.

4 Results

Our data analysis reveals that wearable users may experience adverse effects that are closely related to the concepts of technostress. While the instantiations in our data corresponded to the concepts from the technostress perspective, we noticed differences in their sequence. Specifically, our data indicated that technostress is a circular process that users undergo multiple times as they interact with technology characteristics, perceive technology stressors, and experience strains. As the situations, stressors, and strains repeated, learning and anticipation became important elements in shaping how users' coping behaviors helped them avoid the expected strains. Moreover, we found two technostress patterns in our data–control stress and validation stress–that were related to the drivers of wearable use. Control stress arises from users' drive to control themselves and their performance, while validation stress is related to users' pursuit of validation from the wearable regarding their performance and health status.

The following sections first outline our notion of a circular technostress process, which will serve as a basis for elaborating on the two technostress patterns with wearable use. Then we present separately the two patterns, control stress and validation stress, found in our data.

4.1 Circular Technostress Process

The data analysis made evident that wearable users pass through a circular technostress process that involves appraising wearable characteristics, which leads to the appearance of the wearable stressors that stimulate strains. Our data show that users undergo these process steps multiple times and, consequently, build coping mechanisms and apply coping behaviors to reduce or eliminate the stress. In the following, we outline the technostress process and the categories represented in our data to illustrate its circular nature. Table 2 summarizes the individual categories and the drivers of wearable use, which will be useful in differentiating between the two technostress patterns in the following sections.

While users reported that wearable devices generally offered them good support in, for example, making their performance transparent and visible, evaluating their activities, and offering motivational cues for behavioral change, we identified six wearable characteristics that could provoke stressors: *device-handling*, *automated data management and evaluation*, *goal management and rewards*, *self-tracking*, *social comparison features*, and *activity reminders.* Device-handling relates to the actions users need to take to make the wearable function. The other characteristics are more specifically linked to wearables' functionalities and features. Automated data management and rewards refers to wearables' ability to collect health-related data automatically and to analyze, evaluate, and display it to users in visual dashboards. In contrast, self-tracking must be activated by the user to enable data collection. Such was the case with tracking specific exercises that the wearable did not track automatically, so users had to activate the feature. Goal management and rewards includes setting behavioral goals, receiving status updates with regard to the goals, and recognition for goal attainment. The social comparison features refer to the online social network through which users may share their data and engage in challenges and competitions with others. Finally, activity reminders are automated health-related alerts that ask users to perform a specific behavior, such as taking a number of steps or engaging in a breathing exercise.

Drivers of wearable use	***Wearable characteristics***	***Wearable stressors***	***Wearable strains***	***Coping mechanisms***
• Control: Controlling performance and/or health outcomes • Validation: Seeking approval for behaviors	• Device-handling • Automated data management and evaluation • Goal management and rewards • Self-tracking • Social comparison features • Activity reminders	Related to technological properties: • Inaccuracy • Unreliability • Complexity • Inflexibility Related to transparency and evaluation: • Over-transparency • Over-dependence • Discrepancy between feeling and data	Emotional and cognitive strains: • Feeling restricted in usage • Feeling rejected • Demotivation • Lack of recognition • Guilt • Evaluation issues Behavioral strains: • Obsessive behavior	• Tolerance • Unwillingness to adjust • Distancing • Rationalizing • Compensation • Gaming the system • Alternative validation

Table 2. Technostress categories in wearable use

In the face of adversity, such as when the device was not fully charged, when users forgot to activate self-tracking of their exercise, and when alerts were received when adherence was not possible, users perceived stressors from wearable use. We found stressors that related to the devices' technical properties and stressors that arose from the transparency and evaluation the system provided. Stressors from the technical properties were the (perceived) inaccuracy of the collected data (e.g., inaccurate pulse measurement), unreliability regarding expectations of a function (e.g., problems with display visibility or battery longevity), complexity in using the device as needed (e.g., difficult to understand the meaning of the data), and inflexibility with regard to adhering to requests (e.g., constant and compliant use needed to obtain reliable data). Stressors related to the transparency created by the system included over-transparency by making past and current performances visible, controllable, and comparable at any time (e.g., reminding the user of unsatisfactory performance), users' over-dependence on the wearable data (e.g., heavy reliance on data for performance decisions during activity), and discrepancies between users' feeling and the data (e.g., users expecting that they achieved more than what was reflected in the data).

Based on the stressors, various strains occurred. Our data revealed two classes of strains: 1) emotional and cognitive strains, and 2) behavioral strains. Some users reported feeling restricted in their use when their desire to control parameters was not supported, which gave rise to negative emotions like anger. Others stated they felt abandoned by the device when it was missing or not working as expected, which led to insecurities about health-related decision-making and decreased performance. Moreover, users experienced feelings of demotivation, disappointment, guilt, and even pressure when the data on their performance did not meet their expectations, leading to a perceived absence of recognition for their efforts. Finally, some users experienced difficulties in evaluating themselves when the wearable displayed unsatisfactory or unexpected data, which made them doubt what they felt in their bodies or adapt their feelings to what the devices represented (e.g., feeling less rested as a response to bad sleep data). On the behavioral side, users reported obsessive tendencies, as some of them started focusing extensively on the device and initiated harsh and likely unsustainable changes in their health-related habits.

Our data indicate that users repeatedly passed through the technostress process and its individual elements, and learning processes were set in place because of repeated exposure to stressors and strains. They began to understand and anticipate the situations in which stressors were likely to be present that had led them to experience strains. As a response to such learning and anticipation, users employed coping mechanisms that gave rise to coping behaviors used in various stages of the technostress process. Hence, before they could have appropriate coping behaviors at hand, users needed to experience technostress at least once to set in motion the processes of learning and anticipation.

A female user described undergoing technostress when she felt the wearable was intruding on her life and pressuring her. She addressed learning and anticipation processes as she spoke of that time and about how she figured out an appropriate coping strategy–in her case, adjusting the value she assigned the data and the wearable so it would not negatively influence her:

> *I think I just tried to set up a routine and tried to improve how I get things done. This can be a positive or negative experience. I think in a negative sense, it happened that it put me under extreme pressure. The device has a huge tendency to intervene with or influence my life, and I think I just had to learn and find out for myself how far I*

wanted this thing to get involved in my life and how important the data was to me. I needed to figure it out by using the device. I think that everyone has to find out for themselves where the limit is and how they feel about it, as everyone experiences it in a different way. I think there is a fine line between pressure and motivation. Now I think I have found my way of using it, and I am happy with it. I use the things that have become important to me and I have turned off things I do not want. (Female consultant, age 29)

4.2 Control Stress

Our data indicates that users in a control stress pattern used their wearables to gain control of their performance and health outcomes. Wearables have a variety of features and characteristics that enable users to control and steer themselves. For example, while some users used self-tracking features to control their calorie intake, others controlled their daily activity by leveraging characteristics like goal management and rewards. Some users tried to control their health status by comparing it with their peers using the wearables' social comparison features. Users also used automated data management and evaluation to control activities like running or swimming during or after exercise. In this context, a user who was training to run a marathon emphasized the importance of the wearable data in the training and the wearable as a control and correction device:

The watch has a surveillance role that helps me tackle my training with more moderation. For instance, if I want to run a little slower and achieve a more consistent performance, or if I want to have a moderate start and do a fast final kilometer, then I start thinking about the pace that I need to keep to do so, and I need the watch to see if I have the right pace. But the watch does even more, as I can also observe my pace in real time, so when I aim to have four minutes twenty seconds per kilometer during an interval run, then I can check if I am in the range during the run or check it if I feel like I have slowed down. The wearable really has a good control function." (Male CEO, age 53)

Even though the interviewees generally saw these characteristics as supporting their goal attainment, they could also give rise to stressors. In this pattern, the stressors were related either to the wearables' technical properties' restricting users' desire for control or to situations in which the wearable provided excessive transparency that exceeded users' desire for control. The most prevalent stressors were unreliability, over-transparency, over-dependence, and inaccuracy. Stressors that resulted from wearables' technical properties included failure to collect data accurately, failure to function as expected or intended, and perceptions of complexity. In addition, some users experienced too much dependence on the wearable when they relied heavily on the device to fulfill their desire for control. All these stressors have in common that they result from restricting users' ability to implement control because of inaccurate information or failure to support them in their performance. A female user who relied on her wearable to control her dietary intake explained how unreliability and inaccuracy in capturing and monitoring her activities made it difficult for her to balance her nutrition:

> *Last Saturday, when I was playing golf, I was very unhappy because the wearable did not recognize that I was engaged in sports for three hours, and my wearable does not allow you to set it up yourself afterward, so I'm a bit dissatisfied because this watch doesn't capture certain activities. Also, according to these trackers, I should have very low calorie consumption, which means that I should only eat 1,000 calories a day. That's not much if you know that, for example, one meal of pasta has 800 calories. That bothers me. It especially bothers me when I have been active for two or three hours and it records only thirty-six minutes because I had been thinking, "Cool, if I was this active, I might reward myself and have a burger for dinner," which I can't according to the data. (Female executive assistant, age 42)*

Stressors related to the transparency of personal data are over-transparency and inflexibility. Users perceived over-transparency when the display of personal data went beyond users' expectations and reflected users' behaviors even at times when users did not wish to see it. Moreover, users perceived the device as inflexible and demanding with regard to the regularity and strictness with which they had to use it to obtain the data they needed to be able to exercise self-control. For example, a user stated how the social comparison features created over-transparency:

> *At the beginning, I used it quite often because it lets you observe, for example, what others did on the weekend, so I could see that my friend had been swimming in the morning and in the afternoon, even though she had already been for a walk. And the next day, she did a half marathon and in the evening, she went out with the dog. That made me think, "Wow! I have to do that as well," so I am constantly comparing myself. You see how other people work out, you see how they become better, and then you automatically compare yourself to them. (Female consultant, age 29)*

These stressors led to strains, which became visible as negative outcomes. Some users who perceived stressors that reduced their sense of self-control felt restricted in pursuing and attaining their goals. Others reported feeling rejected and abandoned by a trusted partner. A user who relied on her wearable for sports stated that she felt insecure about her performance and health-related behavior when the wearable was missing, which lead to emotional strains:

I got used to the watch, and it really influences me during the game, so it can be very disappointing if I don't have it with me. It is a reliable partner when I play golf, and if I forget it or forget to charge it for my game, I feel abandoned: Something is missing and I need my partner. It supports me in my game, and I feel a lot safer. (Female project manager, age 53)

In contrast, users who perceived stressors from excessive levels of control showed obsessive behavior in having an extensive focus on the wearable, which even gave rise in some cases to detrimental habits. A user reported that the over-transparency the wearable enabled resulted in addiction-like checking behaviors and frequencies:

Right now I would say it is not that extreme, but there were days or weeks when I got up and the first thing I did was look up how I had slept, whether I had slept better than last night, how much deep sleep I had, and how many REM phases I had. I also looked at it multiple times a day and checked how many steps I had. An important factor may have been that, during the days or weeks when I did competitions with friends, I was really, really addicted to it, and certainly looked at the Fitbit every thirty minutes to see whether my friend or I was in the lead, and I just wanted to win, so I checked it several times a day. I have probably already logged into the app three or four times today to see how well my day is going so far. (Female business student, age 26)

Users employed three kinds of coping mechanisms to reduce the effects of stressors and strains: *unwillingness to adjust*, *distancing*, and *tolerance.* Some users were unwilling to give in to the wearables' demands and applied coping behaviors to ease technostress. For example, they used other devices to track themselves, or they refrained from engaging in certain activities when the wearable was missing or out of battery. Others chose to distance themselves mentally and physically from the wearable and the data it displayed. Such distancing behavior comprised rethinking their attitude toward the data and even deciding to pause the use of particular features for some time. To avoid technostress, one user described how she repeatedly convinced herself not to rely excessively on the display for calorie expenditure, thus mentally distancing herself from the wearable data:

I thought I should lose a little bit of weight and started looking very closely at the calories, but they are not always accurate, so orientating toward them was a negative experience for me. I consciously have to tell myself to ignore it. Even though it is interesting to see that information, I have to remind myself not to take it as a reliable indication. (Female student, age 20)

Others reacted to the restrictions in using the wearable by tolerating its perceived shortcomings and adapting their expectations and behavioral responses to it. For example, they adapted their use habits to be in line with the wearable (e.g., by adjusting their personal schedules to the battery's life) and accounted for the devices' fallibility (e.g., by mentally calculating missing or faulty data). A user who reported having problems activating the sports-tracking feature established the habit of double-checking its activation, thus finding a way to cope with and tolerate the device's unreliability:

> *Now I am checking whether the wearable is really working twice or even three times. For instance, today I checked at the beginning whether the wearable had started to record my session, and I checked whether the wearable was still recording my parameters, such as my heart rate, again during my exercise session. (Female business student, age 26)*

4.3 Validation Stress

Users in the validation stress pattern seek normative approval of their behaviors from their wearables. They use their devices to get recognition for achievements and to corroborate or correct their own feelings, in which users placed less trust than they did the data. Distrusting a subjective feeling and memory, a user described using the wearable's data as a numerical validation:

> *I just have to check with the wearable if something is true or it's just my feeling. Your feeling can deceive you. That's why I like statistics. At some point you will realize how deceptive the impressions about your activity can be, and you can always put a good number behind it to see if your impressions are accurate. Human memory is really not that reliable. (Male self-employed interviewee, age 36)*

Negative effects related to this pattern were associated with wearable's characteristics that support validation. While some users sought validation through the automated collection and display of data, others used self-tracking features to collect validating data. In addition, some users set goals and used the rewards they received for achieving these goals as validation, or they obtained from the wearable social comparison that provided validation. Activity reminders also supported users' need for validation by keeping the users updated about their current performance status. In this context, one user explained that the wearable had become an essential device, as its characteristics enabled validation of her performance, which she perceived as highly motivating:

> *The Fitbit is very important to me because it gives me confirmation. For instance, I can see that "Wow! I really went running," that I ran this and this distance, that I burned this many calories, and that my pulse was that high. So, for me, it is really a bit of a confirmation that I've done a great job because I need a great deal of motivation to get myself out there and go running. I think it's great to go running,*

> *but I don't find it easy to motivate myself, which is why it is extremely important and motivating for me to get confirmation from the Fitbit if I've done something great and that maybe I even improved compared to the last time. (Female business student, age 26)*

Even though validation from the wearable generally motivated users, sometimes the exact same affordances that provided validation invoked stressors. The two prevalent stressors in this technostress pattern were excessive transparency and discrepancy between feeling and data. As in the previous pattern, wearables' creating excessive transparency could lead users to feel disapproval if insufficient or undesirable behaviors were made visible. Discrepancy between users' feelings and data was present if users felt a disconnect between their subjective feeling about their performance and the data, in which they usually trusted. A sports user spoke about the discrepancies between her effort and feeling and the performance shown in the data that sometimes arose:

> *In training, sometimes it can happen that I really put in a lot of effort, and then I see that it was just a medium performance, which can be demotivating. I thought it was a good performance and the watch says, "No, you could have been much faster and better!" (Female medical student, age 28)*

These stressors resulted in various strains since users lacked validation or even perceived disapproval from their wearables. Users reported being demotivated because of frustration and disappointment about the reflection of past performances in the data. Other users experienced feelings of guilt and pressure. Moreover, as a consequence of not receiving the validation they had sought, users felt that the device was not recognizing and appreciating their achievements and efforts. For instance, one user reported being frustrated when the device said she was losing shape shortly before a competition, even though she was training hard to be prepared, feedback that negatively influenced her emotionally before the start of a competition:

> *When the watch told me that I was losing shape shortly before a competition, it was extremely frustrating. As I said, when the wearable pretends to be very scientific, I take it seriously, which might be risky. If it tells I am losing shape before a competition, then that negatively influences me mentally, and I go to the start in a completely different way. (Female nurse, age 53)*

The lack of validation also negatively influenced users' evaluation of their behaviors, abilities, and health status. This strain was particularly apparent with sleep-tracking features. Monitoring and evaluating sleep data caused some users to reassess their sleep and their subjective feelings with regard to it. When presented with data representing low sleep quality, users tended to re-evaluate their feelings, even though they had initially felt well-rested and vital. A user of the sleep-tracking feature gave an account of how the sleep data that her wearable collected influenced her:

> *For example, if it tells me that I have slept badly, but actually I slept for eight hours, that's kind of demotivating because I actually went to bed early and it should reflect that I slept well. Then I ask myself why the data is not as good as when I slept for only six hours. It sometimes even influences my feelings in the sense that I feel more tired that I would if I did not have this information. (Female medical student, age 28)*

Based on these stressors and strains, users eventually developed coping behaviors to circumvent or mitigate the negative effects. Our data indicate four types of coping behaviors employed by users in the validation stress pattern: *rationalizing*, *compensation*, *gaming the system*, and *alternative validation.*

Users engaged in rationalizing the disconfirming experiences by finding logical reasons, explanations, or justifications for not getting a "thumbs-up" from the wearable. For instance, some searched for reasons that other people had achieved higher performances, while others just searched for excuses for their own performance to avoid being demotivated and to be able to improve. One interviewee described how she rationalized her watch's underestimating some of her training sessions:

> *From then on I started not taking the watch 100 percent seriously because I realized that it had a large deficit: the Fenix 5 simply does not weigh long, low-intensity training sessions properly. (Female marketing manager, age 43)*

Users also sometimes engaged in compensating behaviors to avoid future adverse effects. For example, they attempted to make up for missing steps from the previous week. In addition, users sought alternative sources of validation, reporting their accomplishments even when the wearable's validation was missing. Other users sought recognition from external parties (e.g., medical doctors) to overcome missing performance validation and related strains. Finally, users found ways to outsmart the device to receive validation when they were either not eligible for a reward or when they should have received a reward but did not. For example, a user reported how she gamed the system by activating the exercise mode even though she was not exercising so the device would recognize her efforts:

> *Sometimes, when I am in a situation in which I haven't reached my workout goal yet, I activate the workout mode even if I am not working out, such as when I am walking to the bus. Normally, I would never switch on the activity mode because it's a maximum of ten minutes and it is not worth the effort, but if I'm already close to the goal, I sometimes do it anyway. Actually, I do not try to trick the watch, but I try to get additional minutes that I really do but that would not normally be tracked. (Female student, age 22)*

5 Discussion

This study presents two patterns for how users of persuasive technologies experience adverse effects that revolve through a circular process of technostress and mechanisms to cope with them. This section first highlights the most interesting results and discusses how our empirical findings contribute to the literature on persuasive technology and to the literature on technostress. Then it presents implications for practice.

Our results show that persuasive technology users' experiences of adverse effects follow a distinct course that is well represented by the technostress perspective and its elements of technology characteristics, stressors, and strains. We found that users pass through the technostress process multiple times, leading to learning and anticipation of adverse effects, and highlighting the circular nature of experiencing technostress. Following the anticipation of adverse effects, users employ coping behaviors to mitigate adversity in each of the stages of the technostress process. Moreover, we found that the experience of technostress, that is, the manifestations of stressors, strains, and coping behaviors, differed based on two drivers of wearable use. Users who sought to control their behaviors were more likely to perceive stressors related to their wearables' technical properties and over-exercise of control that led to restrictions in goal attainment and obsessive behaviors (i.e., control stress). In contrast, users with the drive to get validation, dissonance between the data and their actual behavior or between the data and their subjective feelings gave rise to negative emotions because of the perception of disapproval.

We make two primary contributions to research. First, we contribute to research on persuasive technology in the health context by providing insights into the under-researched area of adverse effects. In outlining two distinctive technostress patterns that occur with wearable users (i.e., control stress and validation stress), we highlight the stressors and strains experienced and explain the causes of technostress, as well as the coping mechanisms users employ to mitigate stress. Our findings underscore that persuasive technologies that are intended to change users' health-related behaviors generate multifaceted outcomes that go beyond the positive outcomes of using the technologies to include negative outcomes (cf. Benbunan-Fich 2019; de Moya and Pallud 2020). In reaching these findings, we offer an explanation for the contrasting results obtained in experimental studies on the effectiveness of wearable devices in changing users' health-related behaviors. Moreover, since our sample consists of current long-term (> 8 months) users, our results emphasize the importance of users' having adverse effects on the radar, even when they are continuous users. For researchers, this result suggests that they should also consider adverse effects (e.g., obsessive behaviors or destructive patterns) when assessing the success of persuasive health technologies.

Second, we contribute to the technostress literature by highlighting the circular nature of the technostress process and acknowledging the important role of users' learning and anticipation processes in shaping their coping behaviors. While prior studies that have applied the technostress perspective have emphasized describing technology's characteristics, stressors, and strains with organizational (e.g., Tarafdar et al. 2007) and non-persuasive individual IS (e.g., Salo et al. 2019), our study goes a step farther by investigating how users cope with the stress they experience. While some users use beneficial behaviors to cope with technostress from wearable use, such as compensating activities, rationalizations about missing data, and seeking alternative validation, other coping behaviors were detrimental to the users' relationship with the wearable, such as resistance to following the wearable and cheating to obtain the expected rewards. Such harmful coping strategies should be regarded as serious threats to sustainable and effective use, not only to continuance. Therefore, researchers who adopt the technostress perspective should assign a greater role to users' learning and anticipation processes that result in the development of coping strategies.

Our findings also have implications for practice. First, technostress must be anticipated for all wearable users, including continuous, long-term users, so providers should adjust the metrics for successful use to be sensitive to users' experience of negative effects. Such adjustments may include complementing static interaction measures (e.g., app views per day) with more dynamic and feedback-dependent measures (e.g., app views toward the end of the month or app views after receiving negative feedback). Second, the design of persuasive technologies should be based in part on metrics that sense adverse effects and adjust to minimize the threat of negatively affecting users. Such features may be achieved by, for example, providing more advanced personalization of features and a more neutral, non-judgmental representation of behaviors (e.g., hours in the various sleep phases instead of assessing the overall quality of sleep). Providing more transparency in the collection and computation of data and metrics may also help to ease negative experiences. Third, given the importance and potentially detrimental nature of coping behaviors, persuasive technologies should support users in finding and exercising beneficial coping strategies. For example, designers may consider incorporating and promoting the option to adjust inaccurate data manually or establish alerts if tendencies for harmful obsessive behaviors are sensed (e.g., users starving themselves or overtraining).

6 Limitations and Further Research

Our research is subject to some limitations. First, despite the advantages of the narrative interview technique and leaving the structure of the interview to the interviewee, individuals' memory structures might cause biases in the accounts of their use histories toward, for example, extreme events that are easier to remember. Future research may triangulate other research methods to assess our findings quantitatively. In particular, future research could examine the relationship between experiences of strains and the respective coping responses in an effort to design more effective interventions. Second, the sample used in our study has a number of limitations. Because of the purely Swiss sample, the findings' generalizability is limited, and a follow-up study may consider other geographical and cultural contexts to determine whether the identified patterns hold across other cultures. Our sample's including individuals only up to age fifty-four may miss adverse effects that occur specifically with an older population. Future research may investigate age and population groups with lower technology literacy. Moreover, our focus on continuous users of wearable devices limits our findings' ability to describe and explain phenomena experienced by users who quit using their devices. A separate study may shed light at the role of technostress in users' decisions to discontinue use, which could help explain the extraordinarily high attrition rate. Third, given our study's focus on persuasive technologies in the personal health context, the generalizability of our findings across technologies and use contexts is limited, so future research could investigate the extent to which our findings are transferable to other technologies and contexts.

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Research Paper 3:
"Why Users Comply with Wearables: The Role of Contextual Self-Efficacy in Behavioral Change"

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Why Users Comply with Wearables: The Role of Contextual Self-Efficacy in Behavioral Change

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Abstract

Wearables provide great opportunities for improving personal health, but research challenges their capacity to evoke behavioral change effectively. Realizing the full potential of wearables requires a better understanding of users' behavior change processes. Based on self-efficacy theory, we investigate how wearables influence users' perceptions of their self-efficacy and subsequent health behavior. Using narrative interviews with twenty-five long-term wearable users, we show that wearables can have both positive and negative effects on users' perceptions of their self-efficacy and that these perceptions are subject to internal and external contexts, which can positively or negatively affect users' compliance. We also find that the internal context may have a compounding or neutralizing effect on self-efficacy, despite an adverse external context. Our study shows the contextual and transient nature of self-efficacy, thus contributing to self-efficacy theory and research on wearables and offering practical design implications.

Keywords: Self-Efficacy, Behavior Change, Wearable, Context, Compliance, Health

1 Introduction

Wearables are electronic computing devices worn on the body that use sensor technology so users can track their personal activities and parameters like steps, hours of sleep, activities, and food consumption (Mettler & Wulf, 2019). With the emergence of mobile and sensor-based technologies, the prevalence and popularity of wearables that foster a healthful lifestyle—and, generally, systems and applications designed to alter human behavior (Fogg, 2003; Oinas-Kukkonen & Harjumaa, 2009)—have increased rapidly (Khalil & Abdallah, 2013). Wearables, which have become ubiquitous, provide new ways to collect and analyze personal health data and to manage one's personal health through their self-tracking features.

Wearables, which are usually advertised as facilitators of change in health-related behavior, incorporate various behavior change techniques (Lyons et al., 2014; Mercer et al., 2016) to target a variety of health-related behaviors and outcomes (Oinas-Kukkonen, 2013). For example, behavioral patterns can be formed or altered when users build walking into their days or reverse unhealthful eating behaviors. Wearables can also reinforce existing behavioral patterns by providing users with workout histories and statistics, making regular exercise more fun. The health sector places considerable hope in wearables' potential, as the intended behavioral outcomes of wearable use, such as increased activity levels and conscious nutrition, are keys to improving public health and reducing pressure on healthcare providers and insurers (Gimpel et al., 2013).

Accenture Research (2018) reported that 75 percent of consumers surveyed emphasize the importance of technology in managing their health and 48 percent of healthcare consumers use mobile health applications. Accenture Research (2018) also reported that the use of wearable technologies more than tripled between 2014 and 2018, jumping from 9 percent to 33 percent. While more people appear to be using wearables, there is little evidence on which aspects of wearables motivate them to engage and comply with the wearables to change their health-related behaviors (Asimakopoulos, 2017). Despite their ascribed potential, wearables' capacity to evoke behavior change has been questioned. In the context of wearables and health apps, contrasting study results (Brickwood et al., 2019; West et al., 2016) and reasonable doubts concerning the long-term effects (Jakicic et al., 2016) have led to skepticism regarding the technologies' capacity for user adoption and positive behavioral outcomes, especially given reports of high levels of attrition after short periods of use (Ledger & McCaffrey, 2014). Ogbanufe and Gerhart's (2018) research on smartwatches found that the haptic feedback, proximity, and convenience of smartwatches increase users' satisfaction with these wearables and promote their continued use. Our investigation adds to this line of research by investigating the behavioral and contextual factors that influence users' compliance with wearables as the first step in long-term behavioral change. Our literature search for the strongest predictor of behavior pointed us to perceptions of self-efficacy as an important antecedent to behavior (Spagnolli, 2016). We focus on this factor, as there is little evidence on what contributes to self-efficacy with respect to wearables (Asimakopoulis et al., 2017).

Self-efficacy is defined as the person's belief in his or her ability to perform a particular behavior (Bandura, 1977). Self-efficacy is key predictor of the ability to change and maintain a health-related behavior (Strecher et al., 1986). When an individual believes she can perform a certain behavior, such walking ten thousand steps a day, her self-efficacy determines whether she has the confidence, physical ability, and perseverance with which to change her old behaviors (e.g., being sedentary) (Bandura, 1977). Research on the use of wearables for health care has identified self-efficacy as central to users' engagement with health-related applications and devices (Asimakopoulus et al., 2017; Shih et al., 2015) and has suggested that self-efficacy mediates the relationship between technology use and behavioral outcomes (e.g., Liang & Xue, 2009; Myneni et al., 2016). In particular, studies on the influence of behavior-changing technology on users' perceptions of their self-efficacy in the health context have found that technology can strengthen self-efficacy related to the treatment of depression (Kuonanoja et al., 2015; Langrial & Lappalainen, 2016), food consumption (Ronen & Te'eni, 2013), meditation (Laurie & Blandford, 2016), and physical activity (Lim & Noh, 2017). Moreover, scholars have investigated the role of computer-related self-efficacy (Compeau & Higgins, 1995) in performing a variety of technology-related behaviors, such as technology acceptance (e.g., Pavlou & Fygenson, 2006) and coping with malicious information technology (Liang & Xue, 2009).

Despite these research efforts, in-depth insights into wearables' potential to shape users' perceptions of their self-efficacy and their behavior are lacking. Distinguishing among the various forms of self-efficacy is necessary to arrive at such insights. If individuals believe they are able to (with or without prior training) use a wearable device easily, then they have *computer (wearable) self-efficacy*. If individuals believe they are capable of performing a task that a wearable device prompts them to do, such as walking, exercising at a particular pace, or sleeping, then they have *general self-efficacy* with respect to the task that the wearable prompts them to perform. Rieder and Rhyn (2020) mentioned different self-efficacy types than the two types just mentioned. Other authors have identified and measured *relapse self-efficacy* (cf. Sallis et al., 1988), referring to a person's belief in her ability not to relapse, and *scheduling self-efficacy* (cf. Maddison & Prapavessis, 2016; Sallis et al., 1988; Scholz et al., 2016), referring to a person's belief in her ability to make time to engage in a task. The terms used for self-efficacy also show the situationally changing nature of self-efficacy: While a person may be capable of doing a certain behavior, he may relapse under certain conditions or may not be able to make time in a certain context or under certain conditions. Therefore, we adopt a contextual lens to identify the factors that contribute to self-efficacy in the use of wearables and to determine whether there are types of self-efficacy other than those mentioned above.

To determine how context influences self-efficacy, thus enabling compliance with a wearable, we adopt the broad definition of context given by the philosopher Scharfstein: “that which environs the object of our interest and helps by its relevance to explain it. The environing may be temporal, geographical, cultural, cognitive, emotional—of any sort at all. Synonyms for context, each with its own associations, are words such as environment, milieu, setting, and background” (Scharfstein, 1989, p. 1). We consider context as an enabler of or a barrier to self-efficacy and compliance with the wearable. In line with these arguments, we pose the following research question:

How does context influence wearable users’ perceptions of self-efficacy and compliance with wearables?

The following sections present the theoretical background on wearables and self-efficacy theory (generally, and within the IS field). Then we present our method and the results of our analysis. Next, the discussion section provide our contributions to theory, presents the limitations of the study, and proposes further research in the area. Finally, we present how our findings contribute to human-computer interaction (HCI) decisions related to wearable design and use.

2 Theoretical Background

2.1 Wearables

Wearables are electronic computing devices worn on the body and that use sensor technology so users can track parameters like steps, sleep, activities, and food consumption (Mettler & Wulf, 2019). Wearables are composed of physical and digital artifacts (Benbunan-Fich, 2019) and are built into objects like wristbands and clothing that are worn on the body. The proximity to the body allows body functions like heart rate, acceleration, and sleep to be measured (Mettler & Wulf, 2019). The data the sensors collect is paired with data analytics and machine learning applications, which create aggregations that are then displayed either directly via wearable interfaces or via accompanying software programs on smartphones or computers (Benbunan-Fich, 2019). Given wearables’ pervasiveness and their proximity to the human body, they are an ideal means by which to deliver persuasive content that can help users improve their health, such as by increasing physical activity or eating a healthful diet (de Moya & Pallud, 2020). Wearable devices that are designed only to track other health-related parameters, such as fertility, blood pressure, or blood glucose, do not fall into the category that we investigate in this study.

Wearables usually incorporate a variety of behavior change techniques that are designed to induce changes in behavior. Michie et al. (2013) defined these techniques as "observable, replicable, and irreducible component[s] of an intervention designed to alter or redirect causal processes that regulate behavior" (p. 82). The persuasive elements of a wearable that shape behavior can be simple user-interface design elements like digital nudges (cf. Mirsch et al., 2017) and system features (cf. Forget et al., 2008). Michie et al. (2013) provided a comprehensive collection of behavior-change techniques with their 2013 taxonomy of ninety-three behavior change techniques, prominent examples of which include self-monitoring, rewards and threats, goal-setting, and social comparison. Such behavior change techniques can target various outcomes. Oinas-Kukkonen (2013) distinguished among three types of behavioral and cognitive outcomes of behavior-changing technology: compliance change, behavior change, and attitude change. Compliance change refers to simple acts of compliance with an external (i.e., technological) cue provided by the wearable and is the first step of behavioral change. In contrast, behavior change refers to a more fundamental, intermediate- to long-term change in behavioral patterns or routines. Attitude change, the third type of change, is in the cognitive category and is both an enhancement and a catalyst of behavior change. Oinas-Kukkonen (2013) indicated that behavior change is more likely and more stable if the individual has also changed his attitude. Since compliance change is the first step to behavioral and attitudinal change, and is the most observable change, we focus on explaining what brings about compliance with the wearable.

2.2 Self-Efficacy Theory

Self-efficacy theory is one of the dominant behavior-change theories (Oinas-Kukkonen, 2013), so it is a key theoretical underpinning of wearables. Self-efficacy is a key predictor of a change in health-related behavior and maintenance of that change (Strecher et al., 1986). Originating from cognitive psychology, self-efficacy relates to an individual's belief in her ability to perform a behavior and determines the confidence, effort, and perseverance with which she pursues a change in behavior (Bandura, 1977). We use the self-efficacy theory to explain how wearables evoke users' behavior compliance. Next, we determine whether (and how) context affects behavioral compliance.

Bandura's (1977) self-efficacy theory is one of the dominant behavior-change theories. Originally stemming from cognitive psychology—specifically, the treatment of phobias—the self-efficacy theory has been transferred to various research fields and contexts, including education, nutritional science, psychotherapy, management science, and IS. Bandura (1977, 1982) postulated that human behavior is heavily affected by self-efficacy—that is, a person's own beliefs about his or her capacity to perform a behavior—which is necessary to produce desired outcomes.

Individuals' self-efficacy substantially affects whether they initiate a behavior, as well as the effort and persistence with which they pursue it in the face of obstacles and negative experiences (Bandura, 1977, 1982; Stajkovic & Luthans, 1998). Individuals with strong perceptions of self-efficacy see themselves as being equipped with the resources required to perform a behavior, so they can maintain the required level of effort more easily than those whose perceptions of self-efficacy are weak (Bandura, 1997).The stronger (weaker) an individual's perceived self-efficacy, the more (less) likely it is that the desired outcome will result (Bandura, 1982; Stajkovic & Luthans, 1998). Therefore, interventions that promote physical activity must address perceptions of self-efficacy.

When people form their perceptions of self-efficacy, they rely on sources that provide them with information related to their ability to deal with the situation or task at hand: personal accomplishments, vicarious experience, verbal persuasion, and emotional arousal (Bandura, 1977, 1982). Information about personal accomplishments is based on experience and is directly affected by the successes or failures of those experiences. Experience-based self-efficacy can generalize across a variety of situations and circumstances, leading to improved behavioral outcomes and compliance with wearables in diverse contexts and activities. Judgments about one's self-efficacy in performing a behavior can also be based on observing others perform the behavior that results in desirable or undesirable outcomes, which builds on the mechanism of social comparison. However, the informative value of vicarious experience is lower than the information from personal experience, and judgments made based on it are less stable. Information from verbal persuasion can convince individuals of their ability to deal successfully with a particular situation through the power of suggestion, although the impact of verbal persuasion on self-efficacy is lower than that of personal accomplishments and vicarious experience. However, Bandura (1977) emphasized that verbal persuasion combined with other aids and techniques can help to increase one's sense of self-efficacy. Finally, emotional arousal provides information that serves as an interpretive basis of personal competency. Emotional arousal refers to such physical responses as sweating from anxiety and stress. The level of emotional arousal in response to a given cue differs from individual to individual, which helps explain differences in individuals' motivation to undertake or avoid a behavior.

2.3 Self-Efficacy and Information Technology

Self-efficacy theory has been applied in technology-related research for more than three decades, but two streams of the literature on self-efficacy stand out. The first research stream investigates the effect of information technology on individuals' perceptions of self-efficacy, while the second stream focuses on the relationship between perceptions of self-efficacy and the subsequent intentions or behaviors. The extant research presented here can be summarized as suggesting that technology-induced outcome behaviors are mediated by self-efficacy (e.g., Liang & Xue, 2009; Myneni et al., 2016). Therefore, we expect that self-efficacy as it relates to wearable use and to the tasks the wearable suggests affects users' compliance with the wearable's cues.

2.3.1 The effect of information technology on self-efficacy

This comparatively small research stream has treated self-efficacy as a cognitive outcome following technology-mediated interventions. Scholars have examined the effects of interventions like peer-to-peer online communities on students' academic self-efficacy (Alrushiedat & Olfman, 2014). Phua (2013) showed that participation in social networking sites geared to health-related issues significantly influenced people's self-efficacy regarding smoking cessation, mediated by social factors like social support.

While no wearable-specific studies have had this focus, several studies have emphasized other behavior-changing technologies. They have investigated the effectiveness of systems that apply certain kinds of behavior change techniques (e.g., reminders, rehearsal, feedback) on the self-efficacy of people who are suffering from depression (Kuonanoja et al., 2015; Langrial & Lappalainen, 2016) and those who want to change their food consumption (Ronen & Te'eni, 2013). In these contexts, self-efficacy describes individuals' confidence in their ability to self-manage their health conditions. Using a laboratory experiment, Lim and Noh (2017) found that gain-framed performance feedback in a fitness app was more effective in boosting users' exercise self-efficacy than loss-framed performance feedback was. Laurie and Blandford (2016) examined the impact of meditation apps on individuals' self-efficacy regarding their ability to set aside time in their daily schedule to mediate. Their self-efficacy was identified in terms of context (i.e., the ability to manage the task's temporal aspect), not in relation to the task (i.e., meditation) or the computer technology (i.e., the use of meditation app).

2.3.2 Self-efficacy as an antecedent of behavioral outcomes

Self-efficacy as an antecedent of behavioral outcomes has been the subject of many academic investigations. In IS research, self-efficacy has been modeled predominantly as a predictor of technology acceptance. Many studies have applied the self-efficacy construct as an extension to established theories, such as the Technology Acceptance Model and the Theory of Planned Behavior (e.g., Pavlou & Fygenson, 2006; Rahman et al., 2016; Yi &

Hwang, 2003). Only a few IS studies have covered other types of behavioral outcomes that are influenced by self-efficacy, such as coping with malicious information technology (Liang & Xue, 2009). These studies conceptualized self-efficacy as computer self-efficacy (Compeau & Higgins, 1995), which refers to individuals' beliefs about their ability to use computers competently (Compeau & Higgins, 1995) or to use specific types of technology or applications, such as health-related technology (Rahman et al., 2016; Reychav et al. 2019), e-commerce websites (Pavlou & Fygenson, 2006), or class-management systems (Yi & Hwang, 2003). In contrast, Yilmaz (2016) investigated the effect of students' academic self-efficacy on their knowledge-sharing behaviors in an online learning community.

Only two studies have focused on behavior-changing technologies and addressed the role of self-efficacy in changing one's behavior: Oinas-Kukkonen's (2013) conceptual paper proposed the self-efficacy theory as one of the key theoretical foundations for wearables and suggested that perceived self-efficacy mediates the link between the intervention component and the (offline) behavior change induced by the system. Myneni et al. (2016) analyzed the communication content of a community-based wearable that supports smoking cessation and found evidence from various behavior-change theories, including the self-efficacy theory.

In summary, research has provided valuable insights into the effect of behavior-changing technologies and certain behavior-change techniques on self-efficacy and subsequent behavioral change. In accordance with the most of these studies' quantitative nature, they shed light on the statistical relationship between the variables under investigation. However, to clarify wearables' role in shaping individuals' behavior and perceptions of self-efficacy, we must find the underlying mechanisms of this relationship, so we delve into how wearables affect self-efficacy and behavior over time and in varying circumstances.

2.4 The Influence of Context on Perceptions of Self-Efficacy During Technology Use

When forming their perceptions of self-efficacy, individuals rely on the three sources of self-efficacy, but the context substantially influences their perceptions as well. Bandura (1977, 1982) indicated that perceptions of self-efficacy may be undermined by factors related to the context in which a behavior will be performed. Such factors may reside with the task, the situation, or the individual. Research in the IS field has not focused on the context or its influence on the perceptions of self-efficacy that influence behavioral outcomes.

Bamberger (2008) suggested that qualitative research should take context into consideration to build situational and/or temporal conditions into theory. Avgerou's (2019) recent article on contextual explanation argued that context is significant to IS research and suggested that, since research cannot accomplish everything at once, it can do one of two things: (1) Provide the conditions of an IS phenomenon's environment that are factored in IS theory, or (2) identify the mechanisms through which contextual conditions affect the occurrence of a phenomenon. This study seeks to clarify the relationship between context and perceptions of self-efficacy—specifically, to determine which contexts affect high or low self-efficacy and whether and how these perceptions influence the behavioral outcome of complying with the wearable's suggestions for meeting health-related goals.

According to Bandura (1977), task-related factors encompass aspects of the task, including a task's level of difficulty. Studies on barriers to self-efficacy related to physical exercise have incorporated expectations about the affordability and enjoyability of the activity as being potentially restricting if they are not met (Blanchard et al., 2002). Bandura (1977) identified restricting factors that arise from context as including the external and social circumstances under which an action is undertaken (1977). Turning now to health education research, a restrictive context may include external factors (e.g., weather) or a period of stressful life changes (Sallis et al., 1988). As personal factors with a potentially attenuating effect, Bandura (1982) named effort, attribution (see also Stajkovic & Sommer, 2000), and coping capabilities. Studies on exercise-related self-efficacy have also specified personal factors as health issues, the tendency to succumb to temptation, and negative emotions about an activity (Blanchard et al., 2002; Sallis et al., 1988). Rieder and Rhyn (2020) mentioned two types of self-efficacy based on the context: relapse self-efficacy (cf. Sallis et al., 1988), which refers to a person's belief in her ability not to relapse and scheduling self-efficacy (cf. Maddison & Prapavessis, 2016; Sallis et al., 1988; Scholz et al., 2016), which refers to a person's belief in his ability to make time to engage in a task. The terms used for self-efficacy illustrate the situationally changing nature of self-efficacy; for example, a person may be capable of doing a certain behavior but then may relapse under certain conditions or may not be able to make time under other conditions.

3 Method

3.1 Data Collection

We focus our analysis on devices that take the form of wristbands and watches and that track physical activity (IDC, 2018), which are also called wearable activity trackers. Leading providers include Apple, Xiaomi, Fitbit, and Garmin (Statista, 2019).

In emerging fields, where the relationships among concepts are still not fully understood, qualitative research is a better fit than quantitative research (van Aken et al., 2007). Since wearables constitute a new and emerging field, extant research on how wearable use relates to offline behaviors is limited, so we used a qualitative approach to obtain full and rich personal accounts. We followed established principles (Küsters, 2009; Myers, 1997) in conducting narrative interviews with users of wearables to capture individual users' experiences and to obtain a longitudinal picture of the individuals' use history. We used a narrative interview technique (Küsters, 2009), in which the interviewee gives an account of a past event, and determines the organization and structuring of the event. Since the interviewer does not interrupt the narrative, the interview technique avoids common biases, such as social desirability, patterns of interaction in the interview, issues related to wording and placement of questions, and topics and terminology brought in by the interviewer.

We considered the narrative interview to be a suitable technique with which to address our research question. Since we sought to obtain information on the process through which the wearables' features influence users' perceived self-efficacy and compliance with the wearable as behavioral outcomes, the sequential, process-like nature of data generated through narrative interviews was preferable to more structured interview techniques, which would likely put less emphasis on the chronology of the individual interviewee's use history. In addition, as the narrative interview technique involves minimal interference with an individual's narrative, it helps to ensure that only what is relevant to the individual and responsible for shaping his or her compliance and perception of self-efficacy is addressed in the interview without incorporating the bias of the interviewer. Using techniques that require that we bring in our own subjects could jeopardize the individual's coloring and weighting of aspects of the narrative.

We interviewed twenty-five users of wearables who were based in Switzerland, one of the most advanced markets for wearables in Europe, with a market penetration of 7.8 percent in 2019 (Statista, 2019). Using purposive sampling (Miles & Huberman, 1994), we sampled interviewees who were intermediate to long-term wearable users (i.e., past the trial phase). All of our interviewees had used their wearables for more than four months, and some had used them for several years. With this criterion, we sought to capture maximum variation in demographics (i.e., gender, age, profession) so we could identify shared patterns across diverse individuals. In line with the narrative interview technique, no interview guideline was used (Küsters, 2009). Instead, we used a pre-formulated initial stimulus to ignite interviewees' narratives: "Please tell me the story of your activity tracker, from the moment you got it until today." After the interviewees finished their narratives (without interruption), we took up topics they mentioned in their initial narratives to trigger additional accounts. Twenty-two of the interviews were held in person, and three were held via Skype video call. The duration of the narratives varied widely, ranging from nineteen to eighty-seven minutes, with an average of fifty minutes, excluding preliminary chat, the introduction (i.e., regarding the process of the interview, assurance of anonymity and confidentiality), and concluding talk (e.g., thanking the interviewees, small talk, and responding to questions about the research). We recorded the 1,242 minutes of interviews and transcribed them verbatim into roughly 190 pages of text to ensure rigorous and transparent analysis of the resulting data. Interviews and transcriptions were done in the participants' native language, whether German, Swiss German dialect, or English, and were processed by native German and fluent English speakers. The quotations presented in this paper were either made in English or translated into English from German or Swiss German dialect.

Interviewee	*Age*	*Gender*	*Occupation*	*Wearable devices used*	*Main features used*						*Use duration in months (at time of interview)*
					Activity-trackin	*Sports-trackin*	*Heart-rate*	*Competitions*	*Nutrition-*	*Sleep-trackin*	
INT1	25	F	Student	2 × Fitbit	X			X			> 24
INT2	24	F	Student	Jawbone	X		X	X	X		6-12
INT3	62	M	Retired	Polar		X					6-12
INT4	27	F	Legal secretary	2 × Fitbit	X	X		X		X	12-24
INT5	63	M	Medical doctor	2 × Polar, Garmin		X					> 24
INT6	57	F	Project manager	Polar, Misfit	X	X			X		12-24
INT7	41	M	Project manager	Polar		X					> 24
INT8	35	M	Financial analyst	Garmin	X				X	X	6-12
INT9	58	M	Consultant	Garmin, Jawbone, Suunto		X					> 24
INT10	41	M	Entrepreneur	Garmin, Apple	X	X	X				12-24
INT11	41	M	Entrepreneur	Misfit	X			X			6-12
INT12	24	F	Student	Fitbit, Garmin	X	X		X			> 24

INT13	40	M	Computer scientist	Jawbone, Apple	X						12-24
INT14	26	M	Ph.D. student	Xiaomi, Fitbit	X		X	X			6-12
INT15	33	F	Nurse	3 × Garmin		X	X		X	X	> 24
INT16	24	F	Student	2 × Misfit, Garmin, Apple	X	X	X		X		> 24
INT17	25	M	Student	Fitbit	X			X			6-12
INT18	57	M	Managing director	2 × Fitbit	X						12-24
INT19	20	F	Student	Garmin	X	X	X	X			6-12
INT20	18	M	Student	2 × Fitbit	X			X			12-24
INT21	26	M	Bartender	Fitbit		X	X				6-12
INT22	22	M	Student	Garmin	X	X	X				6-12
INT23	40	M	Controller	Fitbit, Apple	X	X					> 24
INT24	39	M	Entrepreneur	Garmin, Fitbit, Misfit, Jawbone, Apple	X						> 24
INT25	57	F	Legal secretary	Fitbit	X	X	X		X		3-6

Table 1. Interviewee characteristics, the wearables used, and their features

Table 1 presents an overview of the study's participants. Our sample consists of nine women and sixteen men from eighteen to sixty-two years of age, all of whom were students and professionals with the exception of one retired individual. The frequency of the wearable's use varied across interviewees and largely depended on the individual's motivation for using it. Most interviewees used the device every day (20 of the 25 interviewees), some also used it at night (7 of the 25 interviewees), and some wore it only when they engaged in sports (5 interviewees). Most used their wearables to track their daily activity, support their sports performance, and improve their health (15 interviewees), although some reported using them to explore the novel technology out of curiosity (10 interviewees). As our research approach relied predominantly on applying pre-identified themes from self-efficacy theory, gaining rich, in-depth narratives from the twenty-five participants allowed us to achieve saturation in terms of the extent to which the data instantiated previously determined conceptual categories (Saunders et al., 2018). Therefore, we stopped coding interviews on this topic after twenty-five interviews.

3.2 Data Analysis

Two of the authors coded the data independently, with regular discussions between them to consolidate findings and avoid subjective interpretations, a step we considered to be central to the credibility of our findings (Wallendorf & Belk, 1989). The results from this analysis and the coding decisions were discussed with other co-authors, who contributed to the synthesis and conceptualization of findings.

Our two-phased data analysis followed Miles and Huberman (1994) in having three types of codes: self-efficacy codes, behavioral outcome codes, and context-related codes. Appendix A shows the coding schema.

In the first phase of the analysis, we conducted deductive coding, where we coded self-efficacy perceptions using categories from self-efficacy theory. We coded for task-related self-efficacy and sought to identify accounts of self-efficacy and the information sources these perceptions were built on (i.e., personal accomplishment, vicarious experience, verbal persuasion, emotional arousal) (cf. Bandura, 1977). We found several sections in which the interviewees referred to their self-efficacy to perform a behavior cued by the wearable. We found accounts of both high and low levels of self-efficacy. With regard to the information sources that the wearable nurtured, we identified examples in the data of all but emotional arousal. We marked where behavioral outcomes and contexts were in the interviewees' accounts.

In the second phase of the analysis, we enriched the existing codes on behavioral outcomes and context with descriptive coding. For behavioral outcomes we used descriptive coding (Myers, 2009) to compare and contrast descriptions of behavioral outcomes and grouped similar sets of behaviors into two categories, compliance and non-compliance. Compliance encompassed behaviors that were in line with the behaviors prompted by the wearable, such as changing food consumption or physical activity, and non-compliance included behaviors that disregarded the prompted behaviors or showed negative reactions, such as defiance or strategies to avoid the cue. Similarly, we applied descriptive coding to contexts to identify the contextual and situational issues that affected the interviewees' self-efficacy and grouped them into internal and external context.

4 Results

4.1 How Wearables Contribute to Individuals' Perceptions of Self-Efficacy

Our empirical data revealed that wearables can influence users' perceptions of self-efficacy regarding performing an activity. In providing information to users, wearables strengthened users' perceptions of their self-efficacy in ways that led to compliance behavior. We found numerous instantiations of wearables providing users with information related to personal accomplishment, verbal persuasion, and vicarious experience—but no examples of emotional arousal—which increased their self-efficacy.

4.1.1 Personal Accomplishment

Our participants reported that wearables provided information on the extent to which they accomplished their goals. This information provided a sense of achievement, increasing their task self-efficacy. Feeling better about their ability to contribute to their health, they increased their compliance with their wearables' cues to engage in healthful behavior. Thirteen of the twenty-five interviewees indicated that seeing their personal accomplishments motivated them to continue using their wearables and/or to comply with their wearables' suggestions. Commonly associated with information about their personal accomplishments were such features as activity goals and the status of their pursuit of those goals, their activity and training histories, trend statistics that showed their performance over time, and badges and rewards.

For example, one interviewee who used the step counter mentioned how the reference values acquired over time acted as self-efficacy information based on personal accomplishment. Interviewee 17 described how the wearable allowed him to see his personal accomplishment:

> *In the beginning, it is hard to interpret what the number of steps means—steps are an abstract measure. But my use of the wearable got better because I eventually had reference values from which I knew, "Ah, I can do this much" or "I've already achieved this many steps," and that helped me pin down the number of steps. After using it for a couple of weeks, I knew what I could achieve on average, what I do on days on which I'm really active, and what makes the difference. (INT 17)*

Thus, the feature helped this participant to make sense of the daily step goals and make realistic estimations about whether the goal was achievable, fostering his self-efficacy in taking up the behavior. Another interviewee pointed out that displays of her progress on her wearable device helped her stay committed and to comply with its requests:

> *It gave me a satisfying feeling–viewing the statistics and the progress I was making. It showed me my progress in the calories I burned during sports, which really motivated me to push myself. It also helped me resist–I don't know–eating a brownie. I didn't want to eat something like that if I had to enter it." (INT 2)*

4.1.2 Verbal Persuasion

Verbal persuasion refers to how verbal encouragement increases a person's self-efficacy and behavioral compliance. Wearables provided many elements of verbal persuasion for our participants. Most common were activity reminders, such as when the wearables say, "Walk another thousand steps to reach your goal today," or "You're on a five-day streak! Keep it up today." Besides activity reminders, verbal persuasion was also conveyed through real-time training parameters, bedtime reminders, or inactivity alerts.

Fourteen of the twenty-five interviewees indicated that the elements related to verbal persuasion helped them feel more capable, increasing their task self-efficacy, and caused them to continue using the wearable and/or to comply with its suggestions. One interviewee described how reminders empowered him to comply with the wearable:

> *Over the course of the day, the Apple Watch sends me a reminder or a message saying, "Hey, you've almost reached your walking goal, but you still have to stand a little more" or "You've stood enough but should walk a little more." It informs me interactively and situationally over the course of the day, not only in the evening with "Hey, you've achieved it" (or you haven't) but "Right now, you should walk for ten minutes to reach your goal, so why don't you go out real quick?" It tells me this in the afternoon at four o'clock, five o'clock, so I feel like I'm being coached and enabled and it's not simply a statistic that is reported afterward. (INT 24)*

Another interviewee spoke about the motivational effect the wearable's persuasive messages had on her. Receiving real-time notifications about the training's impact prompted her to push herself even more:

> *To me, the wearable is an extreme motivator that pushes me and gives me a sense of achievement. There is a real-time rating of how effective my training is, and I always want to build up my form. So if I'm actually done with my training, but the effect is at 2.9 and I know it only takes a few minutes to reach a higher training effect, I will do that. (INT 15)*

4.1.3 Vicarious Experience

Vicarious experience refers to how seeing another person do a task or knowing that another person is able to do a task causes individuals to believe that they can do it too. Vicarious experience is manifested mostly through wearables' social features that connect users to each other and allow them to build a community to follow and track each other's performance. Social features also enabled them either to compete against each other or to work jointly toward the same goals (i.e., challenges). Our interviewees reported that such connections and competition increased their self-efficacy to do as much as or better than the others and to change their behavior to comply with the wearable. Interviewee 4 explained the connection between vicarious experience through competitions and resulting behavior changes:

> *It was surprising. We are a group of people who all had a Fitbit, so we can participate in competitions like who does the most steps, the most stairs. This is very encouraging to me, checking the app and seeing the steps the others have been doing. It encourages me to do better, maybe to walk the ten meters home and not take the tram instead. (INT 4)*

Five of the twenty-five interviewees indicated that vicarious experience motivated them to continue using the wearable and/or to comply with the wearable.

Clearly, wearables can increase users' perceptions of their self-efficacy and, thus, their behavioral compliance by providing features that visualize their personal accomplishments for them, verbally persuade them, and increase their belief in themselves through vicarious experience.

Next, we discuss how context influences users' perceptions of their self-efficacy and compliance with their wearables' suggestions.

4.2 Effect of Internal and External Contexts on Self-Efficacy and Behavioral Outcomes

We defined context as "that which environs the object of our interest and helps by its relevance to explain it. The environing may be temporal, geographical, cultural, cognitive, emotional—of any sort at all." (Scharfstein, 1989, p. 1).

Two types of context emerged from our study's data: internal and external. Table 2 lists the most frequently observed instances of internal and external context. The internal contexts that emerged from our data referred to the users' internal processes, which are endogenous in the sense that the cognitive, behavioral, and emotional responses that constitute the internal context reside with the users' sphere of action and originate from their personalities, individual characteristics, and experiences. Differences in individuals' internal contexts may be due to motivation and commitment to goals; health issues like injuries, illness, or chronic conditions; and ingrained, routinized patterns of action like habits and addictive or compulsive behavior patterns. The internal contexts that emerged from our data were cognitive (e.g., ambition), behavioral (e.g., positive self-reinforcement), and emotional factors (e.g., negative emotions) that contributed to or detracted from the participants' self-efficacy.

As opposed to internal contexts, external contexts refer to the factors that reside outside the individual and influence their self-efficacy. Examples of external contexts from our participants included schedule-related restrictions (e.g., fixed office hours or an examination period), limiting circumstances (e.g., the weather), and activity patterns (e.g., having a sedentary job versus a physical job). In some cases, but not most, the participant had some control over the external context. A feature of some wearables is creating competition by enabling friends or independent participants to see each other's progress. We categorized such competition as an external context since it is not an internal process.

Context Type / **Impact on Self-Efficacy and Compliance**	**Internal Context**	**External Context**
Positive	Awareness Ambition Positive reinforcement Self-punishment Learning effects	Household chores Encouraging competition
Negative	Negative emotions Too much pressure Lack of discipline Temptations Other priorities Other hobbies Negative habits	Work Weather Time of the year Time of the day Discouraging competition

Table 2. Internal and External Contexts and their Influence on Self-Efficacy and Behavioral Outcomes

Our data showed that internal and external contexts can influence individuals' self-efficacy negatively or positively. While interviewees referred to certain internal contexts as contributing positively to their self-efficacy and influencing their compliance with the wearable, they identified other internal contexts as reducing their self-efficacy and compliance with the wearable.

The only external context that the interviewees mentioned as having a positive influence was household chores. Since these chores usually involved physically intense activities, interviewees felt that they facilitated attaining their activity goals. The external context, unlike the internal context, was typically listed as a factor that negatively affected self-efficacy (e.g., bad weather did not allow more steps, their schedule did not allow time to go running). Contexts could be short-term or long-term. Permanent external contexts like chronic medical conditions and permanent internal contexts like strong, ingrained habits imposed special hardship on users in terms of staying committed to the actions the wearable required and led to frequent setbacks.

The impact of only one external context, competition, differed depending on the participants. Some participants identified competition as positively influencing their self-efficacy and behavioral compliance when the competition was fun and the competition's performance was similar to their own (i.e., encouraging competition). Others noted that, when competitors performed noticeably better than the participant did, competition had a negative influence on self-efficacy and behavioral compliance (i.e., discouraging competition). Interviewee 1 highlighted the importance of the opponent's performance being similar to her own, as competing with a friend who had similar activity levels was encouraging and motivating:

> *With my friend, we were approximately on the same level, as we both had around ten thousand steps every day. We used to compare every once in a while, and eventually I'd say, "Hmm ... now she has more than I do, so I should probably see that I do a thousand more per day, rather than just the ten thousand." (INT 1)*

However, when the opponent was too strong, the interviewee's self-efficacy and willingness to follow the competition was impaired:

> *We were a group of people and we used to do competitions, like who got the most steps over the weekend, but there was this guy against whom I didn't stand a chance. Like when I got forty thousand in only one day and was absolutely certain I would win, he had sixty thousand. And at some point, I ran out of steam and stopped competing against him. (INT 1)*

Limitations from the external context often affected the users in such a way that users had little or no faith in their ability to execute the required or planned behaviors. The effect on the individual of the external context's temporal aspect varied quite a bit—anywhere from being momentary or lasting only a few of hours to lasting for three months. For example, some of the participants reported not being able to comply with the wearable during a meeting, which shows the short-term impact of an external context. Others reported being "less inclined to go running during winter" or having "a work schedule that would not allow them to engage in sports on weekdays." In such cases, the participants assessed their ability to engage in the behaviors needed to comply with the wearable as low, so they did not perform them.

4.3 Achieving Positive Behavioral Outcomes in Negative External Contexts

As Figure 1 shows, positive internal contexts increased individuals' self-efficacy, resulting in compliance with the wearable' suggestions, and negative internal context reduced their self-efficacy, resulting in non-compliance with the wearable. Beyond this basic finding, we developed a more in-depth understanding of the interaction between external and internal context.

Compounded Effect. External context that distracted our participants from staying committed to their behavioral goals influenced their internal contexts and led them to doubt their capacity to perform the behaviors the wearables cued. These negative internal contexts ranged from momentary, such as a brief lack of motivation, to much more lasting, such as when users became depressed (internal context) during recovering from an injury (external context), to permanent and deeply impacting users' behavioral patterns. When the external context provided constraints that reduced our participants' self-efficacy, that negative effect was often compounded by negative internal contexts. When they became frustrated or annoyed or felt too pressured, their self-efficacy declined to such low levels that, beyond non-compliance, they stopped using the feature or stopped using the wearable altogether. One interviewee explained how he used the device to increase his walking but was limited by work commitments:

> *Polar and Garmin have this function where you can set your daily step goal and then it will remind you to get up and walk around. I find this totally idiotic. If I have meetings on that day, I cannot just go and walk around. And even if I did–I don't know–ten steps, that's just annoying to be honest. It annoys me if a watch is telling me what to do and what not to do. I know that myself. So after some time, I deactivated it. (INT5)*

Another interviewee mentioned low self-efficacy with regard to achieving the daily step goal during the semester break. Not keeping up with previous accomplishments led to frustration and a guilty conscience and ultimately to taking the wearable off to avoid the resulting adverse emotional state:

> *During the semester break, I always took it off when I had to study because then I wouldn't even get a thousand steps per day. I only moved from the desk to the kitchen and to the toilet, which is practically nothing, and this was so depressing that I just thought "no," and to silence my conscience, I just didn't [put it on] at all. (INT1)*

Neutralizing effect. Some of our participants were able to overcome the effect of external constraints by means of high levels of self-efficacy. In these cases, wearables offered users the strategies and motivational triggers they needed to pursue the required behaviors, despite constraints.

An interviewee with a knee injury that required him to rest for several months reported struggling to find his way back to his daily walking routine. Looking back at the various achievements that the wearable made transparent, he felt challenged by the device, so he decided to pick the walking routine back up. His response to the challenge of the device activated him to comply with it:

> *When I had my knee injury would have been the ideal moment to put it aside. I could have said, "I have a ton of badges …, made hundreds of thousands of steps, and this is it for now," but I thought I had to be able to deal with this stupid little rubber band with four lights. (INT18)*

Another interviewee reported how the wearable's giving him the opportunity to commit to annual goals helped him overcome a negative context:

> *I set an annual running goal of 2.5 thousand kilometers this year. This goal really makes me go out for a run, even if the weather is bad. That really does have an effect, because my mood or the weather or temperature do not keep me from training, so I easily run sixty kilometers per week. (INT 9)*

These examples show how, even when the external context is negative, the internal context determines the self-efficacy and the resulting behavior. When the internal context is also negative, it compounds the impact of the negative external context, even pushing the user to deactivate the wearable's relevant feature, take it off, or stop using it altogether. When the internal context is positive, it neutralizes the impact of a negative external context and pushes the user to face the external context's challenges and continue complying with the wearable. Figure 1 illustrates the neutralizing and compounding effect of the internal context over the external context.

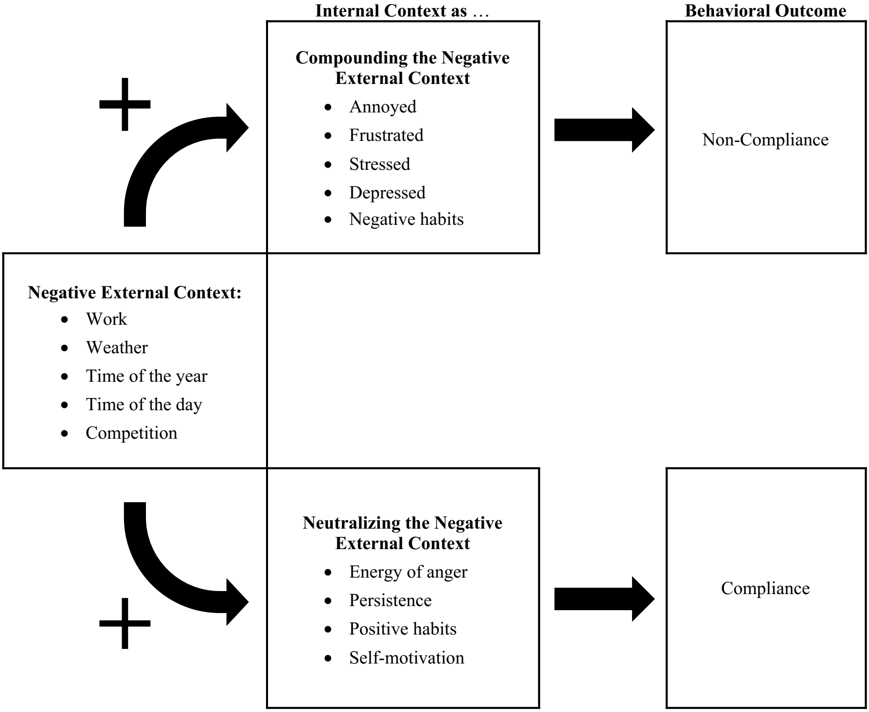

Figure 1. The Neutralizing and Compounding Effect of the Internal Context over the External Context

4.4 The Transient Nature of Self-Efficacy

Compliance behavior is a behavioral outcome from using a wearable, where the users behave in the way intended by the designers of the wearable when the wearable gives cues.

Because of contexts' impact on the participants, those who showed high self-efficacy in positive contexts could show negative self-efficacy when they faced a negative external context and their internal context compounded it. The same interviewee may exhibit different self-efficacy regarding his exercise behavior under different contexts, such as when drinking alcohol or not and the consequent sleep behaviors:

My goal is to have six hours of sleep every night. I realized that this goal, and especially the quality of sleep, heavily influences my behaviors. If I have six hours, I will be very relaxed the next day and can go to work and do some sports after that. But when I've been drinking, my sleep is so much worse that, the day after, I'll end up going to the bar instead of the gym. (INT 8)

Our data revealed that users' perceptions of their self-efficacy were not stable over time but were subject to contextual changes. In other words, despite having had high (low) self-efficacy regarding a specific behavior in one situation, the same user may show low (high) self-efficacy in another situation with respect to the same behavior. As a consequence, differences in behavioral reactions can be observed.

An interviewee who was working part-time spoke of stark contrasts in her confidence in reaching her daily goal of ten thousand steps depending on whether it was a workday. She mentioned restrictive circumstances at work that precluded reaching her daily step goal, but she had no difficulty complying with the cue on her days off:

What I found astonishing was that, when I am at work, I won't achieve ten thousand steps, not in a hundred years. That's actually logical: If I am sitting at a desk all the time, don't do anything in addition, and only go to the toilet twice and grab some coffee three times per day, I maybe make forty-five hundred steps. Whereas on Fridays, when I do not work, I don't have any difficulty reaching ten thousand steps, even if I do not go for a run. As a homemaker, I am rushing around the house all the time, upstairs, downstairs—it's easy. (INT 6)

5 Discussion

This study investigates the use of wearables and their influence on the formation of users' perceptions of self-efficacy and the behavioral outcomes of complying with the wearable. Our analysis of qualitative interviews with twenty-five long-term users of wearables revealed findings that contribute to wearable-specific research and self-efficacy research and that have implications for research and practice.

5.1 Main Findings and Contribution

Our study makes several contributions to research on wearables and on self-efficacy in general. We extend wearable research by shedding light on wearables' influence on the formation of perceptions of self-efficacy and users' behavioral reactions to those perceptions. Our qualitative research approach gave us insights into our participants' interactions and experience with their wearables. By examining the use of commercially available wearables, rather than artifacts that are specifically designed for research purposes, our study allows for investigating the realities of users in a natural setting.

Our first contribution comes from our results that indicate that wearables influence users' perceptions of self-efficacy. As expected, we found that wearables as a source of information strengthened users' perceptions of self-efficacy, which helped them comply with the wearable's suggestions regarding positive health-related behaviors. In self-efficacy theory, Bandura (1977) identified four sources of individual self-efficacy: personal accomplishment, verbal persuasion, vicarious experience, and emotional arousal. We found that three of these applied to wearables and became sources of self-efficacy.

Second, we respond to Avgerou's (2019) call for in-depth research into context by examining how information technologies' impact wearable use for individual heath improvement. Our study revealed that context plays an important role in determining self-efficacy and compliance to the extent that even the self-efficacy of individuals who have task self-efficacy may be reduced significantly by context, such that this reduction causes lack of compliance with the wearable. Therefore, we suggest that the notion of contextual self-efficacy is key to understanding how individuals' task self-efficacy varies across contexts. Contextual self-efficacy is composed of individuals' task self-efficacy, formed based on Bandura's (1977) sources of self-efficacy, as well as the internal and external context. For example, an individual who has a high level of task self-efficacy about running may have a low level of task self-efficacy about running in the rain. Similarly, an individual with a low level of task self-efficacy about running may be have a higher level when he is on vacation.

Third, our findings demonstrate that wearables' effect on users' self-efficacy can be undermined or supported by context. We also underscore individuals' capacity to strengthen their coping skills in the face of constraints to their self-efficacy. In our research we observed two types of contextual variations, external (i.e., arising from the environment) and internal (i.e., residing with the user). The factors that constitute our participants' internal context were described either as positively affecting their self-efficacy and compliance with the wearable or negatively affecting both. Michie et al. (2013) provided various behavior change techniques, among which our study finds that self-monitoring, rewards, goal-setting, and social comparison techniques help with compliance. Compared to the internal factors, all but one of the external factors (household chores) were used in describing barriers to compliance. One external factor, competition, could be either negative or positive, depending on the situation: Encouraging competition could increase self-efficacy and compliance behavior when competitors performed about the same or slightly better than the individual, as this kind of competition created camaraderie, fun, and motivation to do better. On the other hand, when competitors' performance was much better, the individual no longer complied with competition cues, since it was perceived as discouraging. Michie et al. (2013) mentioned social comparison as one of the prominent behavior change techniques. Our findings fine-tune this observation by suggesting that social comparison is helpful only when one compares oneself to those who perform slightly better.

We found that, when the external context provided a constraint, self-efficacy and behavioral compliance declined. However, some participants' self-efficacy and compliance still increased, even in negative external contexts like physical injury. We found that the key to this observation lies in the compounding versus neutralizing role of the internal context: When participants who faced negative external contexts also had negative internal contexts, the internal contexts compounded the external contexts' negative impacts and pushed them beyond lack of compliance to the point of turning off their wearables' feature or taking off their wearables. Under a similarly negative external context, a positive internal context neutralized the negative external context and allowed the participant to continue complying with the wearable.

Finally, we found that perceptions of self-efficacy are not stable over time but vary situationally in either direction depending on a set of internal and external contexts that act as motivators, constraints, compounding constraints, or neutralizers of negative situations. This finding of the transient nature of self-efficacy has significant implications for self-efficacy researchers and contributes to research on self-efficacy by highlighting the contextual aspects of self-efficacy, which is in contrast to the widely used, more generalizable constructs of self-efficacy, such as Bandura's (1977) task self-efficacy or Chen et al.'s (2001) general self-efficacy. We show that the situationally variable construct of contextual self-efficacy may capture and explain momentary shifts and drops in users' self-efficacy and behavioral reactions. We also offer insights into the specificities of constraints to individuals' perceptions of self-efficacy, which the self-efficacy literature has broached only marginally.

Our findings have several implications for research. We suggest that researchers consider measuring contextual self-efficacy when they investigate wearables in general instead of focusing only on computer self-efficacy or task self-efficacy and measuring it under the assumption that the user is operating in ideal conditions. This research would be particularly relevant to changes in health behavior. Studies that use self-efficacy as a dependent variable should also consider measuring self-efficacy at more frequent intervals and in diverse contexts, rather than only at the end of the observation period. This suggestion might be even more useful when applied to interventions that involve serious medical conditions and mental health issues, where a situational drop in self-efficacy and the subsequent non-compliance may have severe consequences.

5.2 Practical Implications

To ensure compliance, we recommend that human-computer interaction (HCI) specialists and designers of wearables take into consideration the three sources of information for developing a high level of self-efficacy—personal accomplishment, verbal persuasion, and vicarious experience—in designing additional features or changing existing features. Our findings suggest taking these sources of information into consideration across contexts to eliminate the negative aspects of internal and external context and bolster positive internal and external contexts to increase long-term use of wearables for health purposes. For example, HCI specialists and designers can identify the negative emotions that the wearable causes and provide the option to set up certain times that they can mute the features to avoid this adversity. Gamifying and creating opportunities to make up for muted times to increase self-efficacy may help those who have to mute their wearables to plan how they can make up for lost time, which would increase their use of the device rather than causing them to give up on it. Since internal contexts are within the individual's control, incorporating mindfulness features into the three sources of self-efficacy to help users stay in touch with their emotions and manage them, thus increasing self-efficacy.

When wearables are introduced to groups like the elderly to manage their health, the introduction often includes only technological training and tips. We recommend including tips and training on how to manage the internal context so as to benefit from the wearable. Such training can be provided in simple videos and provided to users of wearables to make them aware of the wearables' neutralizing and compounding effect and how to set one's internal context more toward the neutralizing end. Moreover, designers and HCI specialists should consider incorporating features that provide positive verbal persuasion and reinforcement to improve the internal context in the face of negative external contexts like cold weather so individuals can neutralize them. Options to personalize such settings by inputting the times/days/conditions in which users may need such emotional support could be provided.

Our findings suggest that HCI designers should understand the transient nature of self-efficacy and design moments that add up to high self-efficacy and compliance. Finally, our research warns the providers of wearables and intervention designers to anticipate the possible adverse effects of behavioral cues and to alleviate the detrimental effect of contextual and personal constraints by, for example, incorporating the chance to program pauses and individualized schedules.

5.3 Limitations and Further Research

As in all qualitative research, its sample and sampling method must be clear to ensure generalization to the right populations. Our study focused on health-focused wearables and used data from individuals who live in Switzerland. We used a narrative interview technique, which is especially valuable in exploring longitudinal, process-like situations. However, the method carries the potential for memory bias. The study's findings could be generalized to similar cultures, but it should be replicated in dissimilar cultures and settings and quantitatively tested to ascertain whether our findings are sensitive to different cultures or can be generalized to all countries.

This study investigated the causes of compliance versus non-compliance, which is the first step in behavioral change. However, studies on long-term behavioral change should go beyond this step and identify what causes individuals to go beyond compliance and to attitude change and behavior change in the form of healthful behaviors that are internalized without being prompted by a wearable. Moreover, the impact that increasing personalization and adaptation of the technology to users' idiosyncrasies may have on perceptions of self-efficacy has to be studied. Finally, future research should look at factors like internal and external contexts to investigate the mechanisms that underlie behavioral change.

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Appendix. Coding Schema

CODE CATEGORY	CODE NAME	DESCRIPTION	REFE-RENCE	EXAMPLE
Self -Efficacy Perception	High Self-Efficacy	Perception of an individual that they are able to do the task that is their goal with using the wearable.	Bandura 1977, 1982	*“ I registered for the Iron Man next summer. It is pretty extreme, after 90 km of cycling, you have to quickly do a half marathon. So I said to myself if I really set goals this high, I need a watch that can support me in this, like giving me all the parameters, analytics, over the past weeks and months so that you can really follow your progress and see what you have to do about it.”* (INT 15)
	Low Self-Efficacy	Perception of an individual that they are not able to do the task that is their goal with using the wearable.		*“ During the exam period, I only did around 1k steps, which is really bad, and if you are not keeping up for several weeks, it will take forever to catch up. I would have to add around 3k per day for the next few weeks to be able to catch up.”* (INT 1)
Information Sources for Self-Efficacy	Personal Accomplish-ment	Personal accomplishment refers to previous experience that shapes individuals’ beliefs in their abilities to perform a task.	Bandura 1977, 1982	*“ It gives you a weekly review of your activities and steps you’ ve made. There were weeks in which I had 15 to 18k steps on average, so this made me think it couldn’ t be that hard to reach the 10k. And also, if I hadn’ t reached the 10k, this motivated me to keep going.”* (INT 19)
	Vicarious Experience	Vicarious experience refers to how seeing another person do a task or knowing that another person is able to do a task enables individuals to believe that they can do it too.		*“ The effect is really–since in my case, a lot of my workmates were using wearables–that you start comparing to one another. And mostly there was this one person who was super motivated and this had the capacity to drag the others along.”* (INT 11)
	Verbal Persuasion	Verbal persuasion refers to how encouraging someone or oneself verbally increases self-efficacy of the person.		*“ The bracelet came with five red bars (on the screen) which showed that I had been inactive. When I didn’ t move for about twenty minutes, like when I was studying at my desk and didn’ t realize it, it started beeping and blinking, saying that I should move around. “* (INT 19)

CODE CATEGORY	CODE NAME	DESCRIPTION	REFE-RENCE	EXAMPLE
Information Sources for Self-Efficacy	Emotional Arousal	An emotional response to cues that are physiological in nature is the basis to form self-efficacy.	Bandura 1977, 1982	E.g.: sweating from anxiety is interpreted as a sign of own incompetence
Behavioral Outcome	Compliance	Indicates a behavior response to the wearable of responding positively to the cue(s) provided by the wearable.	Oinas-Kukkonen, 2013 (cf. Compli-ance Change)	*" It gave me a good overview of the macro- and micronutrients that I consumed over the day, which was very useful. They had these little pie charts indicating, for example, that I had consumed too much sodium or proteins, so I would control that and have less on that day. That helped me to steer my nutrition and fill the nutrients in a more targeted way."* (INT 2)
	Non-compliance	Indicates a behavior response to the wearable of responding negatively to the cue(s) provided by the wearable.		*" Mostly, it' s just me and my housemate taunting each other, like, ' You get zero steps in a day?' , back and forth. One other guy from the research group also uses it so we can see what each other' s been doing on this. There is maybe a tiny competitive element to it, but realistically it is more like we' ll talk about it if we see each other but that' s all."* (INT 14)
Context	Internal Context	Any setting that constitutes individual' s cognitive, emotional, or attitudinal internal environment, which is under the control of the individual.	Adapted from Scharfstein, 1989	*" I try not to let it terrorize me. But I realize that I become very defiant if the watch wants me to do something, but I know that I cannot or don' t want to do that today. I become defiant and start thinking ' Oh, you always have such high demands, just leave me alone!' "* (INT 16)
	External Context	Any context that constitutes external environment of the individual, which is not under the control of the individual. This includes temporal, geographical, cultural factors.		*" I used to go for walks before I had the tracker, but now I am more aware of it and it motivates me to do it even if, for example, the weather is bad. "* (INT 25)

Research Paper 4a:
"Situational Self-Efficacy and Behavioral Responses to Wearable Use"

Authors: Rieder, A., and Rhyn, M.

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Situational Self-Efficacy and Behavioral Responses to Wearable Use

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Abstract

Wearables have the potential to optimize health-related behaviors like physical activity and nutritional intake and to improve individual health outcomes. However, researchers are still doubtful about wearables' capacity to induce behavior change in users. Research that has built on self-efficacy theory has shown that using wearables can influence the users' perceptions of self-efficacy and behavioral responses both positively and negatively, indicating that there is little stability over time. This study will investigate the factors that cause instability in users' situational perceptions of self-efficacy and behavioral reactions. We plan to conduct a longitudinal, quasi-experimental field study with wearable users who self-report in weekly intervals on action-related restrictiveness, contextual restrictiveness, personal restrictiveness, situational self-efficacy, and their behavioral responses over eight weeks. Preliminary results from a pilot study with a reduced sample showed promising results. We will contribute to self-efficacy research by clarifying the factors that cause variations in behavioral responses and finding quantitative support for a situationally varying construct of self-efficacy. We will contribute to practice by deriving implications for the design of wearable devices.

Keywords: wearable, health, self-efficacy, behavior change, longitudinal.

1 Introduction

Fifty-two percent of premature deaths worldwide are caused by such noncommunicable diseases as cardiovascular disease and diabetes, the causes of which can largely be traced back to physical inactivity (World Health Organization, 2010; 2014). Therefore, behavior change interventions that encourage physical activity and healthy nutrition are of key societal interest. Recent advances in mobile and sensor-based technologies have brought about an abundance of health interventions delivered through mobile and/or wearable technology. Wearables allow users to track their activities (e.g., daily steps, sports activity) and vital parameters (e.g., sleep patterns, heart rate) and to review these data using a digital interface to induce behavioral change (Wilson, 2013; Sjöklint et al., 2015). Despite wearables' potential, researchers are still doubtful about their capacity to change behavior—that is, to increase physical activity and decrease sedentary time (e.g., Slootmaker et al., 2009; West et al., 2016)—as well as the sustainability of intervention effects in the long term (Jakicic et al., 2016), which have been investigated in experimental studies (Brickwood et al., 2019). With an exploratory study looking into the processes through which the use of wearable features may lead to behavioral change applying a self-efficacy perspective (Rieder et al., 2019b), evidence on behavioral change in conjunction with wearable use is scarce in information systems (IS) research.

The self-efficacy theory, one of the dominant theories on behavioral change, provides a valuable lens through which to study behavioral change related to wearable use (Oinas-Kukkonen, 2013). Self-efficacy, which refers to an individual's perception of his or her ability to perform a particular behavior, is assumed to affect the initiation of, effort put toward, and the persistence with which individuals pursue an action (Bandura, 1977; 1982). In the wearable context, Rider et al. (2019b) suggested that wearables shape users' behavioral responses indirectly through the influencing factors on users' self-efficacy and, based on the hampering effect of these influencing factors, that users' perceptions of their self-efficacy may vary situationally, indicating the instability of the self-efficacy construct influenced by wearable use. Since Rieder et al.'s (2019b) research is exploratory in nature, it does not specify the influencing factors or the instability of the self-efficacy construct. However, understanding these aspects of wearable use and the related self-efficacy is necessary to explain wearable technology's behavioral effects and to improving the technology's design and the health interventions in which they are employed. Therefore, the research question asks: How do situational factors restrict users' perceptions of self-efficacy and behavioral responses to wearable use?

To address this research question, we will conduct an eight-week, longitudinal, quasi-experimental field study with 150 long-term wearable users who self-report weekly about the circumstances, their situational perceptions of self-efficacy, and behavioral responses related to their most recent occasion of wearable use. Thus, we expect to show the nature of variations in wearable users' situational perceptions of self-efficacy and to shed light on the factors that restrict the situational perceptions of self-efficacy and cause the variations. The research will contribute to research on wearables by explaining why wearable use has a situationally varying effect on perceptions of self-efficacy and behavioral responses that depend on a set of restricting factors. Moreover, by underscoring the situational instability of perceptions of self-efficacy related to wearable use, we demonstrate the theoretical importance of a situationally variable conceptualization of self-efficacy, thereby extending the body of self-efficacy literature. Our findings will also have implications for the design of wearable devices.

The remainder of this paper is structured as follows: Section 2 outlines the theoretical background of our research, including wearables and self-efficacy theory. In section 3, we derive our research model and hypotheses, while section 4 gives an overview of our proposed research method. Section 5 presents the results of our pilot study, and section 6 concludes with an outlook on the expected contributions of our research and important next steps.

2 Theoretical Background

2.1 Wearables for Behavior Change

Wearables are sensor-equipped devices worn on the body and encompass a wide range of devices (e.g., wristbands, glasses, clothing) (Wilson et al., 2013; Sjöklint et al., 2015). Our study focuses on the most prominent category, that is, wearable devices that allow users to track their activities (e.g., daily steps, sports activity) and vital parameters (e.g., sleep patterns, heart rate) using a digital interface either directly on the device's screen or via a smartphone or computer. Positioned as facilitators of changes in health-related behavior, wearables typically use a variety of persuasive techniques (Lyons et al., 2014; Mercer et al., 2016), such as encouraging users to reach a daily step goal and keeping them current regarding their progress. Users who track their nutrition may also decide to cut their caloric intake based on the data the wearable provides.

A large body of literature in medical and nutritional sciences has addressed the effectiveness of wearables in health-related interventions (see Brickwood et al. (2019) for a meta-analysis). Many studies have been optimistic about wearables' effectiveness in improving health-related outcomes; in particular, experimental studies have found positive effects of wearable use on daily steps and energy expenditure. However, other health-related parameters, such as sedentary time and sports activity, have been found to be unaffected by wearable use. A study using wearables in weight-loss interventions found the effect to be inferior to that of standard behavioral interventions and questioned the long-term effectiveness of wearable-related interventions, as effects on body weight were not sustained over the 24-month study period (Jakicic et al., 2016). In short, findings on the effectiveness of wearables in health interventions are mixed.

Studies in IS research on wearables have adopted a more fine-grained perspective and examined, for example, the acceptance (e.g., Lunney et al., 2016) and use (e.g., Becker et al., 2017; Rieder et al., 2019a) of wearables or information-privacy concerns (e.g., Wieneke et al., 2016). Some of these studies have offered first insights into post-adoptive use behaviors and wearable-induced behavioral changes. Rieder et al. (2019b), one of the few IS studies on behavior change, applied the self-efficacy theory to explore how wearables drive behavioral change, finding that wearables may shape behavior either positively or negatively indirectly through evaluations of the context and beliefs related to self-efficacy. They identified such restricting factors as work schedules, injuries, and climatic conditions that are assumed to determine the direction of users' perceptions of self-efficacy and behavioral responses. Given the suspicion that these restricting factors cause the situational variation in wearable users' self-efficacy and behavioral responses, clarifying the factors that play a role in improving wearables and related interventions is essential.

2.2 Self-Efficacy and Restricting Factors

Originating from cognitive psychology, Bandura's (1977) self-efficacy theory is one of the dominant behavior-change theories. It has been transferred to various disciplines, including education, nutritional science, psychotherapy, management science, and IS. At its core lies the assumption that a behavior is strongly affected by individuals' beliefs about their own capacity to perform that behavior; since self-efficacy refers to individuals' perceptions of their own efficacy, it is frequently referred to as "perceived self-efficacy" (Bandura, 1997). To form beliefs or perceptions of self-efficacy, individuals draw on information like feedback, circumstances, patterns of action, and consequences, which they synthesize over long periods of time. Self-efficacy is an important precursor of behavior and behavioral change because it affects individuals' readiness to initiate a behavior and the effort and persistence required to pursue it despite obstacles (Bandura, 1977, 1982; Stajkovic and Luthans, 1998).

IS researchers have applied the self-efficacy theory for more than thirty years, predominantly studying how using IS may influence self-efficacy and its role in IS acceptance. (See Rieder et al., 2019b for a comprehensive literature review.) Several IS studies have found that IS with behavioral outcomes, such as wearables, positively influence users' perceived self-efficacy (e.g., Kuonanoja et al., 2015). Rieder et al. (2019b) also described a negative path from wearable use to low self-efficacy to withstanding behavioral change. Moreover, self-efficacy is regarded as a key determining factor in IS acceptance (e.g., Pavlou and Fygenson, 2006) and in other behaviors related to IS, such as users' coping behaviors related to threats from information technology (Liang and Xue, 2009).

Bandura (1977, 1982) suggested that perceptions of self-efficacy may be restricted by several kinds of factors. First, action-related factors, which particularly encompass a task's difficulty level (Bandura, 1977), including that related to wearables (Rieder et al., 2019b), may hamper individuals' self-efficacy. Studies on barriers to self-efficacy related to physical exercise incorporate the activity's affordability and enjoyability as potentially restricting (Blanchard et al., 2002). Second, restricting factors, which relate to the external and social circumstances in which an action is undertaken (Bandura, 1977), may arise from the situation or the context. Findings from wearable research have supported the restrictive effect of external factors but have not further specified them (Rieder et al., 2019b). Health education research has suggested that a restrictive context is one in which it is impossible to engage in an activity because of other priorities or stressful life changes and external factors like the weather (Sallis et al., 1988). A qualitative study conducted in the context of breast cancer screening indicated the influence of sociocultural factors like social capital, social support, and one's economic condition on women's perceived self-efficacy (Burke et al., 2010). Studies related to diabetes self-management revealed a wide range of barriers, including financial strain, the lack of social support, environmental influences (e.g., climate), and work-related issues (i.e., schedules and traveling) (Adu et al., 2019; Muchiri et al., 2019). Third, personal factors like the effort required, attribution, and coping capabilities may have an attenuating effect on self-efficacy (Bandura, 1982; Stajkovic and Luthans, 1998). Studies on exercise-related self-efficacy specify personal factors like health issues, the tendency to succumb to temptation, and negative emotions related to an activity (Blanchard et al., 2002; Blanchard et al., 2007; Sallis et al., 1988). In the academic context, the personality traits of conscientiousness and neuroticism have been found to influence students' self-efficacy, mediated by self-management skills and perception of situational constraints (Gerhardt et al., 2007). Other studies related to physical activity have found instantiations of all three categories of barriers that influence participants' self-efficacy and engagement in leisure-time physical activity (Cramp and Bray, 2011; Hayotte et al. 2020).

In line with other research on the constraints to self-efficacy, Rieder et al. (2019b) found that wearable users' perceptions of self-efficacy and their subsequent behavioral responses are volatile, based on the presence or absence of restricting factors. The study corroborates that the use of wearable features, together with a set of restricting factors in the environment and related to the action, shapes users' perceptions of self-efficacy related to the behavior the wearable prescribes. Depending on the momentary restrictions these factors impose, the self-efficacy perceptions may be high or low, leading to behavioral responses that differ based on the situation (i.e., performance (non-performance) based on high (low) self-efficacy). This corroboration contrasts with the assumed generalizability of individuals' perceptions of self-efficacy. The construct of general self-efficacy (cf. Chen et al., 2001) refers to the most generalizable form of self-efficacy, which assumes that all previous efficacy-related experience adds up to an overall self-efficacy, although Bandura's (1977, 1997) task-specific self-efficacy construct assumes generalizability only for tasks in the same or closely related domains and does not account for the situational changes in the construct that have been observed with wearable use. Hence, we argue that quantitative investigation of situational self-efficacy and the factors that cause the situational variation is central to our ability to explain self-efficacy in general and self-efficacy related to wearable use and health-related behaviors.

3 Research Model and Hypotheses

Drawing on this theoretical background, we developed the research model shown in Figure 1.

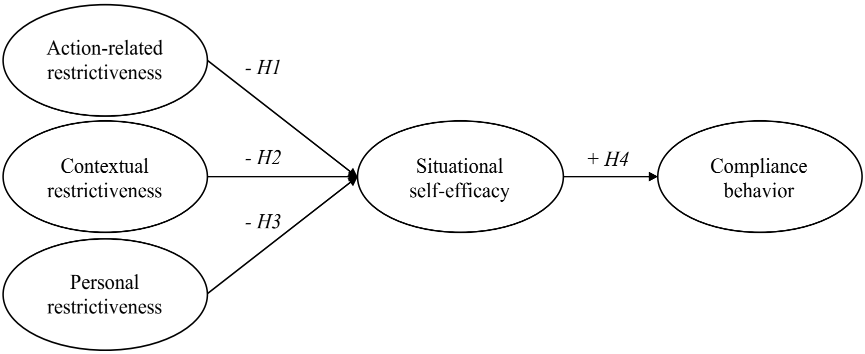

Figure 1. Research Model

When forming self-efficacy perceptions regarding whether to comply with a technology cue or not, wearable users not only rely on the traditional sources of self-efficacy (e.g., personal or vicarious mastery experiences, verbal persuasion; cf. Bandura 1977) but also take into account a variety of factors that might restrict their confidence in their ability to comply. Evidence has suggested that restricting influences may originate from three spheres: the action, the context, and the individual, where *action-related restrictiveness* impairs self-efficacy if the action or task is perceived as too difficult, not affordable, or not enjoyable (cf. Blanchard et al., 2002; Rieder et al. 2019b); *contextual restrictiveness* hampers self-efficacy if the behavior is requested in a situation in which users feel unable to comply because of work- or family-related duties, stressful life changes, or environmental factors (e.g., the weather) (cf. Adu et al., 2019; Muchiri et al., 2019; Sallis et al., 1988); and *personal restrictiveness* has a limiting effect on self-efficacy when health issues, strong negative emotions (e.g., anxiety), or the inability to resist temptation are present (cf. Blanchard et al., 2002, 2007; Sallis et al., 1988; Stajkovic and Luthans, 1998). Building on Bandura's original tripartition, we hypothesize wearable users' situational self-efficacy to be attenuated by the same three constructs:

H1: Action-related restrictiveness has a negative effect on situational self-efficacy.
H2: Contextual restrictiveness has a negative effect on situational self-efficacy.
H3: Personal restrictiveness has a negative effect on situational self-efficacy.

The link between self-efficacy and behavior has been investigated and verified by multiple studies (e.g., Bandura, 1977, 1982; Linde et al., 2006; Strecher et al., 1986). What is new about the relationship proposed in our research model is that our three restrictiveness-related constructs introduce situational variation to the model, such that self-efficacy and compliance behavior vary depending on the situation. This approach is in accordance with Rieder et al. (2019b), which highlights the situational changes in self-efficacy perceptions and reactions to wearable use. We argue that information from attenuating factors is incorporated into an individual's situational (rather than time-invariant) perception of self-efficacy, which then have a direct influence on wearable users' (non-)compliance behavior. Compliance behavior refers to the adherence to the wearable's request (cf. Oinas-Kukkonen, 2013). Despite being a momentary reaction to a technology cue, compliance is an important precursor of higher-level behavioral changes in, for example, habits, routines, or attitudes (ibid.). By becoming routinized and ingrained in users' behavioral patterns, compliance reactions may lead to sustained change in habits, which is needed to leverage the full behavior-changing potential of the technology (Rieder et al., 2019a). With regard to the proposed model's situational focus, we hypothesize:

H4: The higher an individual's situational self-efficacy, the more likely he or she will show compliance behavior.

4 Method

We will conduct a longitudinal quasi-experimental field study to address our research question. The aim of our study is to determine the effect of situational attenuating factors on situational self-efficacy, and an experimental design is an appropriate means to substantiate the proposed causal relationships. In addition, most of our hypotheses' boundedness in the specificities of the use context requires us to study users in their natural setting, making a field study suitable. What's more, given the process-related nature of our research model, a longitudinal design is required to test our hypotheses.

Our study relies on wearable users as participants who self-report weekly on multiple measures regarding their wearable use for eight weeks. Since we consider a natural setting necessary to the research's plausibility and feasibility, we cannot design and manipulate a stimulus object, so random picks are not possible. Therefore, to verify our hypotheses, we use participants' self-reported measures with regard to the presence of restrictiveness and the magnitude of situational self-efficacy to assign the participants to experimental groups. Thus, our study is a quasi-experiment.

4.1 Data Collection

We plan to conduct our experiment with 150 long-term users of Fitbit wearable devices based in Switzerland. With a market penetration of 7.8 percent in 2019, Switzerland is one of the most advanced wearable markets in Europe (Statista, 2019). A snowball sampling strategy will be applied (Goodman, 1961), and additional participants will be recruited using ads on social network sites. The primary inclusion criterion is a minimum of six months use of the wearable, a period sufficient for users to move past the adoption and trial phases and show continuous use behavior (Rieder et al., 2019a). Among the users who meet this criterion, we seek maximum variance in demographics and use cases. We limit our sample to Fitbit users to provide some control of the feature sets and affordances the devices provide. Moreover, Fitbit, which focuses exclusively on self-tracking devices, holds the second-largest market share in the European wearable market, exceeded only by Apple (Statista, 2020), which offers smart watches with a more advanced set of features besides those self-tracking. A sample size of 150 participants is appropriate, recognized standards cite sample sizes of 100 to 150 as sufficient for structural equation modelling, which we will use for our longitudinal mediation analysis (Wolf et al., 2013).

For the experiment's technical implementation, we will use Unipark by Questback, a surveying tool designed for academic purposes. The participants will receive basic, non-deceptive instruction on the purpose of the study (i.e., studying user behavior with wearables) but not on the specific hypotheses to avoid bias (Webster and Sell, 2014). At time t_0, a base survey will be sent out that asks for the participants' demographics and information on the time-invariant control variables (i.e., primary use purpose, user goals, habits, general self-efficacy, readiness to change, locus of causality, personality traits). Also at t_0, the participants will receive the first recurring survey, encompassing questions regarding the features used and the time-varying variables (i.e., restrictiveness of circumstances, situational self-efficacy, and compliance behavior). To prime the participants to think about the situation thoroughly, open questions will ask them to describe their most recent usage, covering the feature they used, the use purpose, and how they used it. The remainder of the survey will ask the participants to relate their situational self-efficacy, the restrictiveness of the circumstances, and their behavioral response to the use situation they described.

The participants will be required to take the survey immediately after receiving it—at the end of the day at the latest—to ensure equal time periods between the surveys across participants. The recurring survey will be sent out every six days so the weekdays on which participants receive them alternate, allowing us to control for possible differences across weekdays. The recurring survey will be repeated seven times after its initial distribution at t_0 (t_1 to t_7). This time span is sufficient to capture multiple instances of variability in situational self-efficacy and behavioral responses and because most seasonal effects (e.g., New Year's resolutions) will not outlast the period. At the same time, an eight-week study horizon seemed to be short enough to minimize dropouts.

4.2 Measures

The measures presented below are only an excerpt of the measures to be used in the study, as are the detailed questionnaires provided in the appendix. Because of space limitations, we focus here on the most central scales on restrictiveness, situational self-efficacy, and compliance behavior.

Restrictiveness: To measure the restrictiveness constructs related to the action, the context, and the individual, as originally proposed by Bandura (1977, 1982), we will draw on factors identified and items used by related literature (Blanchard et al., 2002, 2007; Sallis et al., 1988). The items proposed can be found in the appendix. The participants will be asked to relate to a specific instance of wearable use when responding to the items (using a five-point Likert-scale), which will allow us to compute an average value of restrictiveness for each construct.

Situational Self-Efficacy: Since we lack a specific and situationally variable construct of self-efficacy, we developed a three-item scale for its measurement. We identified three manifestations of self-efficacy that are relevant to our research: 1) task self-efficacy, which refers to a person's confidence in his or her ability to engage in a specific task (cf. Blanchard et al., 2007; Sweet et al., 2012); 2) relapse self-efficacy, marking one's confidence in one's ability to resist relapse (cf. Sallis et al., 1988); and 3) scheduling self-efficacy, representing one's confidence in the ability to plan and make time to engage in a specific task (cf. Maddison and Prapavessis, 2016; Sallis et al., 1988; Scholz et al., 2016). The items proposed can be found in the appendix. The participants will be asked to relate to a specific instance of wearable use when responding to the items (using a five-point Likert-scale, which will allow us to average situational self-efficacy.

Compliance Behavior: In contrast to similar constructs, such as behavior or attitude change, that are not momentarily observable but can be observed only over time (Oinas-Kukkonen, 2013), we address "snapshots" of specific use situations, so the behavioral outcomes may be only two-dimensional, marking either a compliant or non-compliant behavioral reaction with the wearable request. Compliance behavior will be determined by asking whether the participants did or did not change their behavior in the situation.

5 Preliminary Results

We conducted a pilot study to test the validity of our scales (especially situational self-efficacy) and to determine whether the study participants would accept and follow the procedure. The pilot study covered the full time period but used a limited sample of ten participants. Meaningful results in diary studies can be achieved even with samples as small as seven participants (Teuchmann et al., 1999). Keeping our criterion of a minimum use duration of six months, we relied on an ad-hoc sample, although we tried to reach some variation in age, gender, and profession. Our sample consisted of two women and eight men, all aged between 23 to 69 years (M=37.3). The devices used by most participants were by Garmin, Fitbit, and Samsung. Because of the limited sample size, we did not use a full-fledged structural equation model (SEM) with action-related, contextual, and personal restrictiveness but tested the overall effect of the factors that restrict situational self-efficacy (H1-H3) and the effect of situational self-efficacy on compliance behavior (H4). For panel data with repeated measures for each individual, it is important to account for potential random or fixed effects. In our case, the Hausman (1978) test indicates that random-effects models are preferred over fixed-effects models, so we used a random-effects panel linear regression model to test the effect of the restricting factors on situational self-efficacy (Table 1) and a panel logit model to test the effect of situational self-efficacy on compliance behavior (Table 2).

The preliminary results indicate support for our hypotheses, suggesting that, overall, the restricting factors have a negative effect on situational self-efficacy ($\beta = -0.417$; $p = 0.016$) and that situational self-efficacy has a positive effect on compliance behavior ($\beta = 1.192$; $p = 0.013$). The model fit is good (Adj. R2 = 0.392). With regard to the situational self-efficacy construct's internal validity, the Cronbach's alpha yields a value of 0.91, which can be considered excellent (Nunnally, 1978). The promising results of the pilot study have important implications for our future work, as they provide evidence that compliance behavior is affected by a situational form of self-efficacy and that situational self-efficacy is influenced by restricting factors. To examine in more detail the effects of action-related, contextual, and personal restrictiveness on situational self-efficacy, further investigation with a more comprehensive experiment is warranted.

	Coefficient	*Std. Error*	*z-Value*
Intercept	-5.071	1.496	-3.389 ***
RF	-0.417	0.173	-2.408 *
Control: GSE	2.169	0.346	6.278 ***
Adj. R-Sq.	0.392		
Chi-Sq.	43.11 *** (df = 2)		
N[a]	70		

Note: [a] 10 participants; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; RF = Restricting Factors; GSE = General Self-Efficacy

Table 1. Effect of the Restricting Factors on Situational Self-Efficacy

	Coefficient	*Std. Error*	*z-Value*
Intercept	-3.247	1.931	-1.682
SSE	1.192	0.481	2.476 **
AIC	72.59		
Residual dev.	66.59 (df = 67)		
N[a]	70		

Note: [a] 10 participants; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; SSE = Situational Self-Efficacy

Table 2. Effect of Situational Self-Efficacy on Compliance Behavior

6 Expected Contribution and Next Steps

Our findings will contribute to research and practice. They will contribute to self-efficacy research by demonstrating the instability of self-efficacy perceptions in the wearable context, thereby highlighting the importance of a specific and situationally variable self-efficacy construct that complements the established understanding of generalized and stable self-efficacy perceptions. Our research will also clarify the behavioral change processes that are associated with wearable use and the factors that may restrict behavioral change, thus offering an explanation for the conflicting study results regarding wearables' effectiveness and allowing us to predict under what circumstances behavioral change is likely or less likely to occur. In addition, our study will have implications for wearable providers and intervention designers, as identifying the factors that restrict users' compliance with wearables' cues will help to address concrete barriers and obstacles. The volatility of self-efficacy perceptions also indicates the importance of repeatedly persuading of users of their ability to perform a behavior.

Our next steps include recruiting the 150 participants and conducting the experiment in cohorts during summer 2020. After that, we will analyze the data and test our hypotheses.

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Appendix

Questionnaire for situational self-efficacy *(five-point Likert scale, strongly disagree to strongly agree)***:**

In the above situation, I was confident in my ability to:

1) Enable myself to do the behavior (e.g., make time for the behavior) *(scheduling self-efficacy)*
2) Engage in the behavior as needed for my goals (e.g., do the behavior) *(task self-efficacy)*
3) Stick to my behavior goals when facing difficulties or obstacles (e.g., not give up on the behavior) *(relapse self-efficacy)*

Questionnaire for restrictiveness of circumstances *(five-point Likert scale, strongly disagree to strongly agree)***:**

Did you encounter any negative circumstances or obstacles in your situation?

1) I had other work-related priorities (e.g., I had an important deadline coming up) *(contextual)*
2) I do not enjoy the activity (e.g., I do not enjoy running) *(action-related)*
3) It was impossible for me to do the activity because of the context (e.g., I could not run outside because there was a thunderstorm) *(contextual)*
4) I felt strong negative emotions (e.g., I was afraid of running in the dark) *(personal)*
5) The activity was too difficult (e.g., I cannot run 20km) *(action-related)*
6) I am going through a stressful personal life change (e.g., I recently lost a close family member) *(contextual)*
7) The temptation not to engage in the activity/behavior were too high (e.g., I was invited to dinner and could not resist the unhealthy food served) *(personal)*
8) My health did not allow me to do the activity (e.g., I had a 40° fever) *(personal)*
9) I did not have the funds to do the activity (e.g., I could not afford the green fee) *(action-related)*
10) I had other priorities related to family and friends (e.g., my son was sick) *(contextual)*
11) None
12) Other (please specify) *[with text field]*

Questionnaire for compliance behavior *(multiple choice)***:**

Following the situation in which you used your wearable, how did you react?

- I did not change my behavior.
- I adjusted my behavior to what the wearable intended.

Research Paper 4b:
"The Transient Nature of Self-Efficacy in Technology-Enabled Health Behavior Change"

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Working Paper

The Transient Nature of Self-Efficacy in Technology-Enabled Health Behavior Change

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Abstract

Persuasive systems have the potential to optimize health-related behaviors like physical activity and nutrition and to improve individual health outcomes. However, researchers are still doubtful about their capacity to induce behavior change. Research that has built on self-efficacy theory has shown that persuasive systems can exert dual effects on users' perceptions of self-efficacy and behavioral responses, indicating that there is little stability over time. This study investigates the factors in users' internal and external context that cause instability in situational perceptions of self-efficacy and subsequent behavioral reactions. We conducted a longitudinal field study with seventy-six continuous wearable users who self-reported in weekly intervals on internal and external context, situational self-efficacy, and their behavioral responses over seven weeks.

Keywords: persuasive system, wearable, health, self-efficacy, context, behavior change, longitudinal

1 Introduction

An unhealthy lifestyle is one of the key factors of mortality worldwide (World Health Organization, 2019). Therefore, combating diseases of affluence, like high blood pressure, type 2 diabetes, and overweight lies at the core of health promotion endeavors (World Health Organization, 2010). Typically, health promotion and behavior change interventions encourage physical activity and healthy nutrition—the key factors to improve personal health (World Health Organization, 2014). With the advancements in mobile and sensor technologies, health interventions are increasingly delivered through digital technologies, like wearable self-tracking devices or mobile health apps (Kraft et al., 2009; Coughlin and Stewart, 2016). Designed to induce changes in users' health-related behaviors, these technologies are viewed as persuasive systems (Fogg, 2003). Persuasive systems are socio-technical information systems (IS) that aim to change users' behaviors and attitudes in a predefined way (Oinas-Kukkonen and Harjumaa, 2009). For this, persuasive systems make use of various persuasion strategies, for example, self-monitoring, goal-setting, and social support (Mercer et al., 2016). Unsurprisingly, persuasive systems have gained traction with health insurance companies offering persuasive systems as part of their preventative health programs (Kuchler, 2019), organizations employing the technology as part of occupational health initiatives (Fingas, 2020), and commercially available devices (e.g., Fitbits) reaching mainstream adoption (Statista, 2020).

Despite the manifold application areas and confirmed potential in some contexts (e.g., Kuonanoja et al., 2015; Brickwood et al., 2019), persuasive systems' capacity to effectively induce changes in users' health behaviors continues to be contested. Doubts have been raised regarding their effectiveness to increase physical activity and decrease sedentary time (e.g., Slootmaker et al., 2009; West et al., 2016)—as well as the sustainability of intervention effects in the long term (Jakicic et al., 2016). These effects are underscored by reports on the phenomenon of high abandonment rates after only short periods of use (Ledger and McCaffrey, 2014). While IS research has yielded a rich body of literature on the adoption of persuasive systems (e.g., Fox and Connolly, 2018; Kim and Park, 2019) and user's continuous use behaviors (e.g. Prasopoulou, 2017; Mettler and Wulf, 2019), knowledge regarding the users' behavior change processes remains scarce.

The self-efficacy theory, one of the dominant behavior change theories, provides a valuable perspective to study health behavior change related to persuasive systems use (Oinas-Kukkonen, 2013). Self-efficacy, which refers to an individual's perception of his or her ability to perform a particular behavior, is assumed to affect the initiation of, effort put toward, and the persistence with which individuals pursue an action (Bandura, 1977; 1982). Various factors residing with the person and their environments have been identified to influence and restrict individuals' self-efficacy (e.g., Blanchard et al., 2002; Sallis et al., 1988; Adu et al., 2019). In particular, users' internal and external context has been found to play an important part in shaping self-efficacy perceptions and behaviors related to persuasive systems use (Rieder et al., 2020b). Hence, we set out to understand the complex relationship between users' persuasive systems use, the surrounding context, and the effect on self-efficacy percepts and behavioral outcomes. Therefore, our research question asks:

How does context influence users' perceptions of self-efficacy and behavioral outcomes of persuasive systems use?

To answer our research question, we conducted a seven-week longitudinal field study with seventy-six continuous, long-term users of persuasive systems. In weekly self-report surveys, participants were inquired about their current use behaviors and context in which they occurred, the related self-efficacy perceptions, and their behavioral responses. This allowed us to extract the relationships between context, self-efficacy perceptions, and behavioral responses, and to capture variations and the reasons behind these variations.

This research makes several important contributions to research and practice. We contribute to IS research on persuasive systems in untangling the relationship between the context of persuasive systems use and behavioral outcomes thereby shedding light at users' behavior change processes. Moreover, by underscoring the variable and transient nature of users' perceptions of self-efficacy we demonstrate the theoretical importance of a situationally variable conceptualization of self-efficacy, thereby contributing to the self-efficacy literature. Last, our findings have implications for the design of persuasive systems for health promotion.

2 Background

2.1 Persuasive Systems

Persuasive systems are information systems that are designed to alter users' behaviors and attitudes in predefined ways (Oinas-Kukkonen and Harjumaa, 2009; Fogg, 2003). To this end, they use various persuasion strategies (Michie et al., 2013), for example, self-monitoring, goal-setting, rewards and threats, and social support (Mercer et al., 2016). Persuasive systems have gained traction in the context of health promotion and healthcare (Kraft et al., 2009) where they are assigned immense potential to improve personal health outcomes and mitigate the effects of diseases of affluence, like overweight, raised blood pressure, and type 2 diabetes, that are caused by insufficient physical activity and unhealthful nutrition (World Health Organization, 2014). Persuasive systems for health take different shapes (e.g., computer programs, mobile apps, wearable self-tracking devices) and target various health-related behaviors (e.g., physical activity, nutrition, sports, sleep, mental health, disease self-management). Prominent examples include such systems as Fitbit, MyFitnessPal, Runtastic, and MoodKit.

Research has attested persuasive systems' capacity to improve a variety of health outcomes with users. In a meta-review of the effectiveness of wearable activity trackers, Brickwood et al. (2019) conclude that, persuasive systems are effective in increasing physical activity and caloric expenditure, and reducing sedentary periods. Also, information systems studies have reported various positive cognitive and behavioral effects on users. For example, smartwatches were found to help users improve individual performance after profoundly exploring new ways to employ the technology (Ogbanufe and Gerhart, 2020). Moreover, wearable activity trackers were shown to empower users in enabling them to self-improve with regard to various aspects of behavior (de Moya and Pallud, 2020), and it was indicated that wearable lifestyle devices afforded both positive cognitive outcomes, such as learning and self-knowledge as well as improvements in behavioral outcomes, such as sports performance and increased physical activity (Rieder et al., 2020a). Moreover, persuasive health systems use was found to positively affect psychological well-being with self-determined users (James et al. 2019).

Despite these promising prospects, literature from information systems and medicine also revealed various shortcomings of persuasive systems. Several studies questioned persuasive systems' capacity to improve users' health outcomes, i.e., physical activity levels, aerobic fitness, and body weight and body composition (e.g., Slootmaker et al., 2009; West et al., 2016) and growing skepticism is directed toward the sustainability of the induced behavioral changes. For instance, Jakicic et al. (2016) indicated that despite positive effects on users' weight loss at six months, the benefits were not sustained over the full study period of 24 months. In information systems, research has been concerned with identifying the reasons for abandoning persuasive systems (e.g., Attig and Franke, 2020), emphasizing the roles of motivation loss due to negative feedback, privacy concerns, and developing obsessive tracking behaviors. Moreover, investigating post-adoptive use of persuasive systems, information systems scholars warned against potentially harmful effects of persuasive system with regard to emotional, cognitive, and behavioral outcomes. Schmidt-Kraepelin et al. (2019) highlighted various unintended side effects from gamification used in health behavior change support systems, i.e., adverse motivational effects, informational noise, reduced integrity of exercise, demoralization of users, and overstepping boundaries. Moreover, Rockmann (2019) found that the motivational affordances of fitness apps may harm users' perception of their competence, thus weakening continuance intentions. De Moya and Pallud (2020) demonstrated that persuasive systems had the power to leave users disempowered as they imposed surveillance on them, which gave rise to feelings of guilt. Last, Rieder et al. (2020b) indicated that persuasive systems under certain circumstances lowered users' self-efficacy toward a health behavior and eradicated their adherence to system-cues.

While prior research highlights the complex (James et al., 2019) and dualistic (cf. De Moya and Pallud, 2020; Rieder et al., 2020b) nature of outcomes following persuasive systems use, little is known about the processes that shape these outcomes. To investigate users' processes of persuasive systems use and behavior change, we take a self-efficacy perspective to understand how factors with users' and their environments influence behavior.

2.2 Self-Efficacy Perceptions and Restricting Influences

The elf-efficacy theory is one of the dominant behavior-change theories, and a key theoretical underpinning of persuasive systems (Oinas-Kukkonen, 2013). Self-efficacy is a key predictor of a change in health-related behavior and maintenance of that change (Strecher et al., 1986).

Self-efficacy relates to an individual's belief in their ability to perform a behavior and determines the confidence, effort, and perseverance with which they pursue a change in behavior (Bandura, 1977). Originating from cognitive psychology, Bandura's (1977) self-efficacy theory has been transferred to various disciplines, including education, nutritional science, psychotherapy, management science, and IS.

At its core lies the assumption that a behavior is strongly affected by individuals' beliefs about their own capacity to perform that behavior; since self-efficacy refers to individuals' perceptions of their own efficacy, it is frequently referred to as "perceived self-efficacy" (Bandura, 1997). Self-efficacy is an important precursor of behavior and behavioral change because it affects individuals' readiness to initiate a behavior and the effort and persistence required to pursue it despite obstacles and negative experiences (Bandura, 1977, 1982; Stajkovic and Luthans, 1998). Individuals with strong perceptions of self-efficacy see themselves as being equipped with the resources required to perform a behavior, so they can maintain the required level of effort more easily than those whose perceptions of self-efficacy are weak (Bandura, 1997). The stronger (weaker) an individual's perceived self-efficacy, the more (less) likely it is that the desired outcome will result (Bandura, 1982; Stajkovic and Luthans, 1998). Therefore, interventions that promote physical activity must address perceptions of self-efficacy (Strecher et al., 1986).

To form perceptions of self-efficacy, individuals draw on various kinds of information, such as personal experience from past successes or failures, accomplishments of peers, encouragement, and physiological states (Bandura, 1977, 1982). However, research has shown that individuals' perceptions of self-efficacy may be restricted by several kinds of factors. Drawing on Scharfstein (1989), a recent study by Rieder et al. (2020b) differentiated between internal and external context that influence users' self-efficacy perceptions related to persuasive systems for health promotion. Internal context is described as the factors and processes that "reside with the users' sphere of action, and originate from their personalities, individual characteristics, and experiences" (Rieder et al., 2020b, p.7). Research identified various factors falling under internal context. For example, it was suggested that if a task or behavior to be performed exceeds a specific level of difficulty, individual's self-efficacy will deteriorate (Bandura, 1977); this relationship was supported in a study related to health behaviors and wearable use (Rieder et al. 2020b). Other studies with respect to physical exercise found that a particular activity's affordability and enjoyability had potentially restricting effects on individuals' self-efficacy (Blanchard et al., 2002). Moreover, personal factors were identified to have a potentially attenuating effect on self-efficacy (Bandura, 1982; Stajkovic & Luthans, 1998)—specifically health issues, an individual's tendency to succumb to temptations, and negative emotions related to an activity in the context of physical exercise (Blanchard et al., 2002; Blanchard et al., 2007; Sallis et al., 1988). In the academic context, the personality traits of conscientiousness and neuroticism have been found to influence students' self-efficacy, mediated by self-management skills and perception of situational constraints (Gerhardt et al., 2007).

In contrast, external context was described as "the factors that reside outside the individual and influence their self-efficacy" (Rieder et al., 2020b, p.8), which involves constraints related to external and social circumstances outside the influence of the individual. Various individual factors that fall under this category have been identified. For example, health education research suggested that it may be impossible to engage in an activity because of other priorities or stressful life changes and external factors like the weather, negatively influenced individuals' self-efficacy (Sallis et al., 1988). A study in the context of breast cancer screening indicated the influence of sociocultural factors like social capital, social support, and one's economic condition on women's perceived self-efficacy (Burke et al., 2010). Studies related to diabetes self-management revealed a wide range of barriers, including financial strain, the lack of social support, environmental influences (e.g., climate), and work-related issues (i.e., schedules and traveling) (Adu et al., 2019; Muchiri et al., 2019).

An exploratory study on self-efficacy in the context of wearable use described interactions between different factors influencing individuals' self-efficacy perceptions (Rieder et al., 2020b): While it was indicated that wearables themselves influenced users' perceptions of self-efficacy, contextual factors related to specific use situations either reinforced or neutralized each other in their impact on self-efficacy. Thereby, the authors explained users' situationally variable behavioral outcomes when using wearables (ibid.). We seek to add to this line of research as we wish to further the understanding of the situational nature of self-efficacy, the subsequent behaviors, and the factors causing this phenomenon.

3 Research Model and Hypotheses

Drawing on this theoretical background, we developed the research model shown in Figure 1.

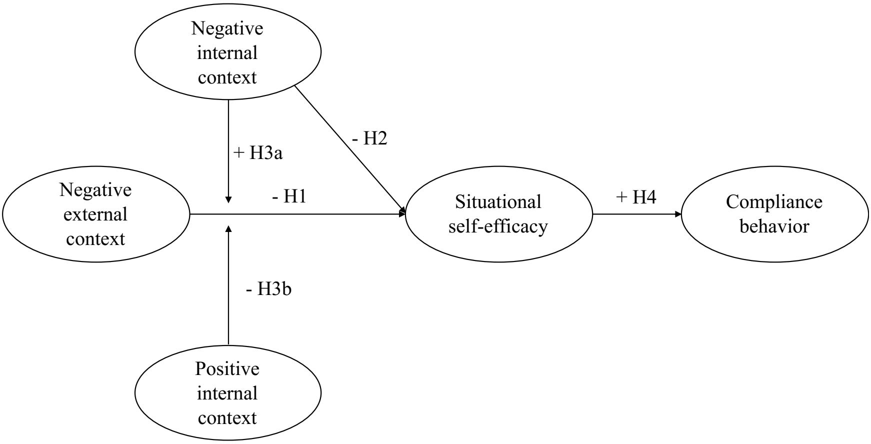

Figure 1. Research Model

When forming self-efficacy perceptions regarding whether to comply with a technology cue or not, users of persuasive systems not only rely on the traditional sources of self-efficacy (e.g., personal or vicarious mastery experiences, verbal persuasion; cf. Bandura, 1977) but also take into account a variety of constraints that might restrict their confidence in their ability to comply.

Research has suggested that restricting influences originate from two spheres: internal context, which consists of factors that "reside with the users' sphere of action and originate from their personalities, individual characteristics, and experiences" (Rieder et al. 2020b, p.7), and external context, which refers to "factors that reside outside the individual and influence their self-efficacy" (p.8).

With respect to users' internal contexts, empirical evidence suggests that perceptions of self-efficacy to perform health-related behaviors can be impaired by such factors as, perceived excessive task-difficulty (Bandura, 1977), limited enjoyability (Blanchard et al., 2002; Muchiri et al., 2019), individuals' health conditions (Adu et al., 2019; Blanchard et al., 2002; Cramp and Bray, 2011; Muchiri et al., 2019; Rieder et al., 2020b), negative emotions related to the behavior (e.g., anxiety, stress) (Sallis et al., 1988; Strecher et al., 1986; Blanchard et al., 2002; Cramp and Bray, 2011; Muchiri et al., 2019; Rieder et al., 2020b), and negative habits (Muchiri et al., 2019; Rieder et al., 2020b) that—together with a lack of discipline—impede individuals' ability to resist temptation (Muchiri et al., 2019; Sallis et al., 1988; Stajkovic and Luthans, 1998). Based on this logic, we hypothesize:

H1: A negative external context lowers individuals' situational self-efficacy.

Turning toward the external aspects constituting context, it was shown that such factors as work- and family-related duties (Sallis et al., 1988; Adu et al., 2919; Blanchard et al., 2002; Burke et al., 2010; Cramp and Bray, 2011; Rieder et al., 2020b), going through a period of stressful life changes (Sallis et al., 1988), affordability of the activity (Burke et al., 2010), competition that is perceived as discouraging (Rieder et al., 2020b), and environmental factors like the weather or winter time (Adu et al., 2019; Muchiri et al., 2019; Sallis et al., 1988) interfered with individuals' perceptions of self-efficacy to perform health-related behaviors. Hence, we hypothesize:

H2: A negative internal context lowers individuals' situational self-efficacy.

However, internal and external contexts not only act in isolation, but also have the power to reinforce or neutralize each other. From the field of health promotion, it is known that negative external context and negative internal context can interact with one another and create a compounded effect (Rieder et al., 2020b). Compounded effects were observed, for example, when individuals were on a tight schedule due to work-related duties and then received disconfirming feedback from a persuasive system which causes them to enter adverse emotional states (e.g., pressure, guilt) (ibid.). The compounded effect causes self-efficacy dropping to such low levels, that the behaviors even go beyond non-adherence with cues, for example, discontinuance of specific features of the technology. Based on this argumentation, we hypothesize:

H3a: A negative internal context increases the negative impact of a negative external context on individuals' situational self-efficacy.

The reverted reasoning applies when internal context is positive. Given a negative external context, positive internal context has the power to neutralize or mitigate the negative effect on individuals' perceptions of self-efficacy (Rieder et al., 2020b). Despite external constraints, individuals can overcome the situation and arrive at high levels of self-efficacy. Neutralizing effects were observed, for example, when the weather or climate kept individuals from performing an activity, but cues from the persuasive system that reminded them of their activity goals helped them face the external constraints and engage in the activity anyway (ibid.). The neutralizing effect helps to cancel out the effects from negative external context, so that individuals' self-efficacy is unaffected, and behaviors are done as if external context was neutral. Thus, we hypothesize:

H3b: A positive internal context lowers the negative impact of a negative external context on individuals' situational self-efficacy.

Last, the link between self-efficacy and behavior has been investigated and verified by multiple studies (e.g., Bandura, 1977, 1982; Blanchard et al., 2007; Linde et al., 2006; Strecher et al., 1986). What is new about the relationship proposed in our research model is that our two constructs for context introduce situational variation to the model, such that self-efficacy and compliance behavior vary depending on the situation. This approach is in accordance with Rieder et al. (2020b), which highlights the situational changes in self-efficacy perceptions and reactions to wearable use. We argue that information from internal and external is incorporated into an individual's situational (rather than time-invariant) perception of self-efficacy, which then have a direct influence on wearable users' (non-) compliance behavior.

Compliance behavior refers to the adherence to the technology's request (cf. Oinas-Kukkonen, 2013). Despite being a momentary reaction to a technology cue, compliance is an important precursor of higher-level behavioral changes in, for example, habits, routines, or attitudes (ibid.).

With regard to the proposed model's situational focus, we hypothesize:

> *H4: The higher an individual's situational self-efficacy, the more likely he or she will show compliance behavior.*

4 Methodology

We conducted a longitudinal field study to address our research question. The aim of our study was to determine the effect of factors restricting users' perceptions of self-efficacy and behavioral compliance. Most of our hypotheses' boundedness in the specificities of the use context requires us to study users in their natural setting, making a field study suitable. What's more, given the process-related nature of our research model, a longitudinal design is required to test our hypotheses. Our study relies on wearable users as participants who self-report weekly on multiple measures regarding their wearable use for seven weeks.

4.1 Data Collection

For our study, we used data from seventy-six long-term users of wearable self-tracking devices based in the German-speaking area (i.e., Switzerland, Germany, Austria, Liechtenstein). The participants were recruited using ads on various social network sites, dedicated exercise and nutrition websites, gyms and sports clubs, and the university of two of the authors. The primary inclusion criterion was a minimum of six months use of the wearable, a period sufficient for users to move past the adoption and trial phases and show continuous use behavior (Rieder et al., 2019). Moreover, participants had to be fluent in German in order to take the surveys.

While we did not limit participation to a specific brand or model of wearable devices, only users who used their devices for self-tracking of health-related parameters were admitted for participation in the study. Hence, we excluded those who only used productivity or social features of their devices (e.g., instant messaging, calendars, voice assistants).

A sample size of 140 participants was appropriate, recognized standards cite sample sizes of 100 to 150 as sufficient for structural equation modelling, which we used for our longitudinal mediation analysis (Wolf et al., 2013).

For the experiment's technical implementation, we used Unipark by Questback, a surveying tool designed for academic purposes. The participants received basic, non-deceptive instruction on the purpose of the study (i.e., studying user behavior with wearables) but not on the specific hypotheses to avoid bias (Webster & Sell, 2014). At time t_0, the introductory survey was sent out that asks for the participants' demographics and further information on the time-invariant constructs (i.e., primary use purpose, goals). Also, at t_0, the participants received the first recurring survey, encompassing questions regarding the features used and the time-varying variables (i.e., internal and external context, situational self-efficacy, and compliance behavior). To prime the participants to think about the situation thoroughly, open questions asked them to describe their most recent usage. The remainder of the survey asked the participants to relate their situational self-efficacy, constraints from the context, and their behavioral response to the use situation they described.

The participants were required to take the survey immediately after receiving it—at the end of the day at the latest—to ensure equal time periods between the surveys across participants. The recurring survey was sent out every six days so the weekdays on which participants receive them alternate, allowing us to control for possible differences across weekdays. The recurring survey was repeated a total of eight times (t_0 to t_7). This time span was deemed sufficient to capture multiple instances of variability in situational self-efficacy and behavioral responses and because most seasonal effects (e.g., New Year's resolutions) will not outlast the period. At the same time, seven-week study horizon seemed to be short enough to minimize dropouts.

4.2 Measures

The measures presented below are an excerpt of the central measures used in the study (i.e., external context, internal context, situational self-efficacy, and compliance behavior). The questionnaires can be found in the appendix.

Internal and External Context: To measure the restrictions from users' contexts, we used two constructs internal context and external context as proposed by Rieder et al. (2020b).

We drew on individual factors identified and items used by related literature (cf. section 3). The included items can be found in the appendix. The participants were asked to relate to a specific instance of wearable use when responding to the items (using a five-point Likert-scale), which allowed us to compute an average value of restrictiveness for both constructs.

Situational Self-Efficacy: Since we lack a specific and situationally variable construct of self-efficacy, we developed a three-item scale for its measurement. We identified three manifestations of self-efficacy that are relevant to our research: 1) task self-efficacy, which refers to a person's confidence in his or her ability to engage in a specific task (cf. Blanchard et al., 2007; Sweet et al., 2012); 2) relapse self-efficacy, marking one's confidence in one's ability to resist relapse (cf. Sallis et al., 1988); and 3) scheduling self-efficacy, representing one's confidence in the ability to plan and make time to engage in a specific task (cf. Maddison and Prapavessis, 2016; Sallis et al., 1988; Scholz et al., 2016). The items used can be found in the appendix. The participants were asked to relate to a specific instance of wearable use when they responded to the items using a five-point Likert-scale.

Compliance Behavior: In contrast to similar constructs, such as behavior or attitude change, that are not momentarily observable but can be observed only over time (Oinas-Kukkonen, 2013), we address "snapshots" of specific use situations, so the behavioral outcomes may be only two-dimensional, marking either a compliant or non-compliant behavioral reaction following wearable use. Compliance behavior will be determined by asking whether the participants did or did not change their behavior in the situation.

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Appendix

Table A. Recurring Questionnaire.

Construct	Questionnaire: English translation	Questionnaire: German original
Situational self-efficacy	Q) Think about the situation where you used that feature, why you used it and what behavior it prompts you to have Please indicate how much you agree to the following statements. In the above situation, I was confident in my ability to: A) [*5-pt Likert scale; Strongly disagree–Disagree–Neither agree nor disagree–Agree–Strongly agree]* • Enable myself to do the behavior (e.g., make time for the behavior) • Engage in the behavior as needed for my goals (e.g., do the behavior) • Stick to my behavior goals when facing difficulties or obstacles (e.g., don't give up on the behavior)	F) Denken Sie an die vorhin beschriebene Ausgangssituation, in welcher Sie Ihr Wearable genutzt haben: Bitte geben Sie an, wie sehr Sie den folgenden Aussagen zustimmen. A) *[5-pt Likert-Skala; Trifft von und ganz zu–Trifft eher zu–Unentschieden–Trifft eher nicht zu–Trifft überhaupt nicht zu]* • In der Situation war ich zuversichtlich, dass ich mich dazu bringen kann, das Verhalten auszuführen (z.B. Zeit freizumachen). • In der Situation war ich zuversichtlich, dass ich das Verhalten so ausführen kann, wie es für die Erreichung meiner Ziele nötig ist. • In der Situation war ich zuversichtlich, dass ich an meinen Zielen festhalten kann, auch wenn sich mir Schwierigkeiten oder Hindernisse in den Weg stellten.
Negative context (internal and external)	Q) Did you encounter any negative circumstances or obstacles in the above situation?	F) Denken Sie wieder an die Ausganssituation zurück. Sind Sie in der Situation negativen Umständen oder Hindernissen begegnet?

	Please indicate which of the following negative circumstances you encountered. A) (5-pt Likert scale; Strongly disagree–Disagree–Neither agree nor disagree–Agree–Strongly agree) *[External context]* • I had other work-related priorities. • It was impossible for me to do the activity because of the weather. • I did not have the funds to do the activity (e.g., I could not afford the gym fee) • It was impossible for me to do the activity because of the time of the day. • I was discouraged because my competitors were too strong. *[Internal context]* • I had other priorities related to family and friends. • I did not have the time because I was engaging in other hobbies. • I did not enjoy the activity. • I felt strong negative emotions. • The activity was too difficult (e.g., I cannot run for 20km).	Bitte geben Sie an, welchen negativen Umständen Sie begegnet sind. A) *[5-pt Likert-Skala; Trifft von und ganz zu–Trifft eher zu–Unentschieden–Trifft eher nicht zu–Trifft überhaupt nicht zu]* *[External context]* • Ich hatte andere berufliche Verpflichtungen. • Ich konnte das Verhalten wegen des Wetters nicht ausführen. • Ich konnte es mir nicht leisten, das Verhalten auszuführen. • Ich konnte das Verhalten wegen der Tageszeit nicht ausführen. • Ich war entmutigt das Verhalten auszuführen, weil meine «Mitstreiter» zu stark waren. *[Internal context]* • Ich hatte andere familiäre/soziale Verpflichtungen. • Ich hatte keine Zeit, weil ich anderen Freizeitaktivitäten nachging. • Das Verhalten hat mir keinen Spass gemacht. • Ich empfand starke negative Emotionen. • Das Verhalten war zu schwer (z.B. 20 km laufen).

	• I am going through a stressful personal life change (e.g., I recently lost a close family member; I recently started a new job). • The temptations not to engage in the activity/behavior were too high (e.g., I was invited to dinner and could not resist the unhealthy food served) • My health did not allow me to do the activity. • I felt under pressure. • I fell back into old patterns (e.g., I had a snack before going to bed). • Other *[open text field]*	• Ich mache gerade eine stressige Phase durch (z.B. Familienangehörige verstorben; neue Arbeitsstelle). • Die Versuchungen waren zu gross (z.B. Ich war zum Abendessen eingeladen und konnte dem ungesunden Essen nicht widerstehen). • Aus gesundheitlichen Gründen konnte ich das Verhalten nicht ausführen. • Ich fühlte mich unter Druck gesetzt. • Ich bin in alte Muster zurückgefallen (z.B. Snack vor dem Zubettgehen). • Andere *[Freitextfeld]*
Behavioral response	Q) Following the situation in which you used your wearable, how did you react? A) *[Multiple choice]* • I adjusted my behavior in line with the wearable. • I did not change my behavior.	F) Wie haben Sie sich in der Ausgangssituation verhalten? A) [*Einfachauswahl]* • Ich habe mein Verhalten entsprechend der Vorgabe des Wearables angepasst. • Ich habe mein Verhalten nicht angepasst.
Neutralizing effects	Q) What helped you overcome negative circumstances? Please indicate which of the following you encountered. A) (5-pt Likert scale; Strongly disagree–Disagree–Neither agree nor disagree–Agree–Strongly agree)	F) Was half Ihnen, die negative Umstände zu überwinden? Bitte geben Sie an, wie stark die untenstehenden Aussagen auf Ihre Ausgangssituation zutreffen. A) *[5-pt Likert-Skala; Trifft von und ganz zu–Trifft eher zu–Unentschieden–Trifft eher nicht zu–Trifft überhaupt nicht zu]*

	• I motivated myself to do the behavior. • I punished myself for previous unfavorable behavior. • Other people motivated me to do the behavior (e.g., friends, medical doctor) • I realized how effective it was to maintain the behavior. • Doing the behavior has become a habit. • I turned my negative emotions into energy. • Other activities in my daily life made doing the behavior easier (e.g., walking the dog, cleaning the apartment). • My ambition did not allow me to yield. • I learned how good it is for me to do the behavior.	• Ich habe mich dazu motiviert, das Verhalten auszuführen. • Ich habe mich für früheres, schlechtes Verhalten bestraft. • Andere Menschen haben mich motiviert, das Verhalten auszuführen (z.B. Freund*innen, Ärtz*innen). • Ich habe gemerkt, wie effektiv es ist, das Verhalten beizubehalten. • Das Verhalten ist für mich zur Gewohnheit geworden. • Ich habe meine negativen Emotionen in Energie gewandelt. • Andere Aktivitäten in meinem Alltag haben es mir erleichtert, das Verhalten auszuführen (z.B. mit dem Hund rausgehen, Hausarbeiten). • Mein Ehrgeiz hat es mir nicht erlaubt, einzuknicken. • Ich habe gemerkt wie gut es mir tut, das Verhalten auszuführen.

Research Paper 5:
"Affordances and Behavioral Outcomes of Wearable Activity Trackers"

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Affordances and Behavioral Outcomes of Wearable Activity Trackers

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Abstract

Wearable Activity Trackers (WATs) are often ascribed the ability to reduce health risks by promoting physical activity and healthful eating habits. However, research has shown that their use does not always lead to behavior changes. Using the affordance lens, this study investigates how WATs' material features facilitate behavioral outcomes, as users interpret WATs in light of their personal health-related goals. Using narrative interviews with twenty-five WAT users, we found two categories of affordances—learning affordances and behavior-focused affordances—leading to three behavioral outcomes: behavior change, compliance change, and remaining with the status quo. Moreover, we identified four types of users (based on their goal configurations) that actualized different affordances and showed different behavioral outcomes. While some types of users fundamentally changed their daily routines as a result of using WATs, others simply complied with technology cues or did not change their behavior at all. Our results have several implications for research on WATs and WATs' design.

Keywords: Wearable, Affordance, Behavior Change

1 Introduction

Physical inactivity is a key cause of an array of noncommunicable diseases, such as cardiovascular disease, diabetes, and cancer, which cause as much as 52 percent of premature deaths worldwide (World Health Organization, 2014). Since engagement in physical activity can alleviate the long-term health risks of raised blood pressure, high blood sugar, and overweight (World Health Organization, 2010), societal interest lies in interventions that can induce positive behavioral changes in physical activity and diet. With the emergence of mobile and sensor-based technologies, an increasing number of health interventions are delivered through mobile and wearable technology. “Wearables” are electronic computing devices worn on the body that use sensor technology so users can track such personal activities and parameters as daily steps, sedentary time, activity, nutrition, and sleep behavior (Sjöklint et al., 2015). This study focuses on wearable activity trackers (WATs), devices that allow users to track of their physical activity and other behaviors. Typically, WATs aim to shape their users’ health behaviors by applying persuasive principles and techniques, so such devices are “behavior change support systems” (Oinas-Kukkonen, 2013). Not surprisingly, the health sector has considerable optimism about WATs’ potential. The intended behavioral outcomes of WAT use, such as increased activity levels and conscious nutrition, are keys to improving public health and reducing pressure on healthcare providers and insurers (Gimpel et al., 2013).

Naturally, research has emphasized the physical and health-related outcomes of WATs’ use. A series of effectiveness-directed trials on WATs’ use from medical and nutritional sciences have shared optimistic results (e.g., Barwais et al., 2013; Finkelstein et al., 2016). Brickwood et al.’s (2019) meta-analysis underscored the positive effects of WATs’ use on health-related parameters like increased physical activity, reduced sedentary periods, and caloric expenditure. However, several studies have also indicated that WATs are not effective in improving such outcomes (e.g., Slootmaker et al., 2009; West et al., 2016). In addition, the focus of most studies in Information Systems (IS) has lain on investigating WATs’ use, which is an inadequate proxy for behavior change and behavioral outcomes in general (e.g., Becker et al., 2017; Kari et al., 2016; Rieder et al., 2019). Therefore, we lack an empirically founded explanation for how these behavioral outcomes are achieved. Such an explanation will complement and contribute to previous research on WATs and help providers of WATs improve their technologies.

As a theoretical foundation, the concept of affordances is particularly well-suited to explaining why users might interact with the same technology in different ways and experience different outcomes (Leidner et al., 2018). The affordance perspective is an appropriate theoretical lens through which to investigate the complex intertwining between users’ goal configuration, the possibilities for action provided by WATs’ material properties, and the resulting behavioral outcomes (Volkoff and Strong, 2013). Against this background, our research question asks: *How do the affordances provided by WATs enable behavioral outcomes?*

To address this question, we conducted narrative interviews with twenty-five users of WATs, which gave us an in-depth understanding of these users' use history and how WATs helped them identify and realize opportunities for new behaviors.

The present research makes several contributions to theory and practice. First, we contribute to WAT-specific research by being first to link the affordances commercially available WATs provide to behavioral outcomes. Second, we offer an explanation for the actualization of different affordances resulting in different outcomes by identifying user types based on user goals. Third, our research provides practical insights for WAT design. Based on the affordances and behavioral outcomes enabled by certain WAT features identified in our study, WAT providers can assess whether these are in line with those intended by the designers and decide about necessary adaptations.

The paper proceeds as follows. First, we present the theoretical background on wearables, the affordance perspective, and its role in IS as well as in wearable-specific research. Then, we present our method and the results of our analysis, before concluding with a discussion of our results, limitations, and proposals for further research.

2 Theoretical Background

2.1 Wearables for Behavior Change

"Wearables" is an umbrella term for any electronic computing device worn on the body that is using sensor technology to let users track their personal activities and vital parameters (Sjöklint et al., 2015). The term encompasses a wide range of devices (e.g., wristbands, glasses, clothing); though we focus on wearable devices that allow users to track physical activity and vital parameters: WATs. Wearable devices that exclusively track other health-related parameters, such as fertility, blood pressure, or blood glucose levels, are thus not part of our analysis. WATs, usually taking the form of wristbands and smartwatches, are the most popular category on the wearables market (IDC, 2018).

By providing users with insights into their physical performance through self-tracking of such parameters as steps, sleep, sports activities, and food consumption, WATs allow users to self-optimize (Gimpel et al., 2013, Sjöklint et al., 2015). Users can interact with WATs directly over the device's screen or via mobile applications, which are typically accessible using a smartphone. WATs are usually positioned by their providers as facilitators for changes in health behavior. For this purpose, they incorporate persuasive techniques to target a variety of health-related behaviors and outcomes (Lyons et al., 2014; Mercer et al., 2016). Such persuasive techniques encompass but are not limited to gamified elements, such as badges or challenges (Lyons et al., 2014). A typical persuasive technique is the step counting feature that can help users to form or alter behavioral patterns like introducing daily walks, while the nutrition tracking feature can support the reversal of unhealthy eating habits. WATs can also reinforce existing behavioral patterns, for example, by providing users with workout histories and statistics, making regular exercise more fun and appealing. Thus, WATs can be regarded as behavior change support systems (BCSS), defined as "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" (Oinas-Kukkonen, 2013, p. 1225). BCSS are persuasive systems or applications designed to alter behavior in a predefined way (Oinas-Kukkonen, 2013; Oinas-Kukkonen and Harjumaa, 2009). BCSS aim to accomplish certain outcomes, i.e., changing users' behaviors, which also includes reinforcing existing behavioral patterns or taking up entirely new ones (Oinas-Kukkonen, 2010), so the magnitude of the change the system aims to induce can vary.

Oinas-Kukkonen (2013) distinguishes between three types of changes: Compliance change, behavior change, and attitude change. The compliance change is lowest in magnitude and easiest to achieve, since it involves simple acts of complying with an external (i.e., technological) cue. In contrast, behavior change includes a more fundamental, intermediate- to long-term change in behavioral patterns or routines. Attitude change, the third type of behavioral change, is a cognitive category, which is regarded as an enhancement of behavior change, yet at the same time as catalyst of behavior change. Oinas-Kukkonen (2013) indicates that behavior change is more likely and more stable if the individual has also changed her attitude.

In medical and nutritional sciences, a large body of literature has investigated the effectiveness of wearables in health interventions. Such studies predominantly ran randomized controlled trials to quantitatively assess the effectiveness of wearable-mediated interventions as compared to non-wearable or non-technology controls. Many studies found support of the effectiveness of wearables to influence health-related outcomes. Prominent outcome measures that were found to be improved by WATs included the number of daily steps, minutes of moderate to vigorous physical activity, sedentary time, calorie expenditure, nutritional intake, body weight, and body fat percentage (Brickwood et al., 2019; see also Barwais et al., 2013; Finkelstein et al., 2016). Other studies however have obtained non-supporting results of WATs' effectiveness to influence health-related outcomes. These results dampen the prospects of WATs as drivers of health behavior change by not finding significant effects of WAT use on parameters like physical activity, aerobic fitness, body weight and composition (e.g., Slootmaker et al., 2009; West et al., 2016) or highlighting that benefits which are indeed achieved are not sustained over time (e.g., Jakicic et al., 2016). Turning towards IS research on wearables, we see that only a small fraction of the literature has looked into the user experiences related to wearable use (e.g., Becker et al., 2017; Kari et al., 2016; Rieder et al., 2019). However, none of these studies are addressing behavior change or the processes that lead to behavior change following wearable use. While providing valuable insights, prior research does not shed light on how exactly the material features of WATs allow for behavior change as the users interpret WATs in light of their individual goals. However, such an understanding is necessary for WAT providers to design WATs and interventions in a more targeted way.

2.2 Affordance Perspective

The concept of affordances has its origins in the field of ecological psychology. Gibson (1986) emphasizes that people who look at an object do not initially see its qualities so much as what it will enable them to do. Thus, affordances describe “what is offered, provided, or furnished to someone or something by an object” (Volkoff and Strong, 2013, p. 822). Affordances, which arise from the relationship between an artifact and a goal-oriented actor, refer in IS research to the possibilities for action offered by the material properties of an IT artifact to a user in order to achieve a goal (Volkoff and Strong, 2013). The user’s interpretation of affordances depends on the objectives she pursues in using the technology. For example, depending on the goal of an actor – whether a person wishes to eat dinner or to fix a light bulb – a chair may afford an opportunity for sitting or for climbing on. Thus, the same technology or object can afford different possibilities for action to different people. Being regarded as underlying mechanisms, affordances – in contrast to the concrete outcomes of an action – are not observable per se; rather they must be actualized by an actor to lead to outcomes and thereby become empirically observable (Volkoff and Strong, 2013). In order for an affordance to be actualized it must be perceived by an actor who then enacts the afforded potential for action (Volkoff and Strong, 2017). This also implies that the possibility exists that an affordance might never even be actualized or perceived (Volkoff and Strong, 2013). The empirically observable state or condition reached after actualizing an affordance is referred to as outcome (Volkoff and Strong, 2017). Affordances are complex assemblages of technological properties, users, and the relation between them, which is why they can provide or affect other affordances and produce various outcomes in a non-deterministic way (Leidner et al., 2018; Volkoff and Strong, 2017).

Leidner et al. (2018) underline the need to conceptually distinguish between the materiality of an IT artifact, its use, the affordances such use provides and the resulting outcomes. Materiality refers to those properties and features of an IT artifact, encompassing hardware (i.e., physical materiality) and software (i.e., digital materiality), that have some stability across contexts and across time (Lehrer et al., 2018). While technology use describes the direct interaction of the user with IT features, affordances are made possible by technology use. Outcomes, in turn, result from the actualization of an affordance, not from technology use. Leidner et al. (2018) use the example of commuting on a train to illustrate the conceptual differentiation: Since the train is the technology and the goal of the actor is getting to work, riding on the train marks using the technology, while the affordances arising from the relation between the technology and the user goals might include working, sleeping, or conversing with other people. The outcome relates to the affordances actualized and would – in the case of working on the train – for example, involve that the actor got more work done in a day.

The affordance lens has received considerable interest in the IS research community to explain how technologies are involved in shaping user behavior at an individual level (e.g., Mettler and Wulf, 2019) and within organizations (e.g., Lehrer et al., 2018; Strong et al., 2014; Volkoff and Strong, 2013). In this study, we use this theoretical lens to investigate the affordances provided by the material features of WATs and how these affordances result in behavioral outcomes. The relational nature of affordances make the concept particularly well-suited for explaining why users might interact with the same technology in different ways and experience different outcomes (Leidner et al., 2018).

In the context of wearable technology, a handful of authors have taken up the affordance lens. On the one hand, studies taking a design perspective, have tapped into the concept, using affordances as requirements wearable devices have to fulfill (Benbunan-Fich, 2018; Guest et al., 2017; Zhang and Lowry, 2016). Another stream, more closely related to our study, has investigated the perceived affordances of WATs. Affordances of WATs have been investigated in the workplace (e.g., Mettler and Wulf, 2019; Yassaee and Winter, 2017). In addition to identifying affordances, Mettler and Wulf (2019) found that different user types of wearables in the workplace perceived different affordances. Moreover, Rockmann and Gewald (2018) studied the affordances of activity tracking systems, which are however not worn on the body, but sports apps, while Bower and Sturman (2015) identified the pedagogical potential of wearable technology from an educational perspective. Focusing on perceived affordances, none of these papers have covered actualized affordances nor investigated the behavioral outcomes of WAT use. By considering actualized affordances and behavioral outcomes of WATs, our research seeks to take a different stance of affordances, namely, regarding “affordances as a completed action” (cf. Lanamäki, 2016, pp. 132).

3 Method

Since empirical evidence of the actualized affordances and behavioral outcomes of wearable use is scarce, we sought to obtain full and rich personal accounts using a qualitative approach. We conducted narrative interviews with WAT users, following established principles (Chatman, 1978; Küsters, 2009) in order to capture individual user experiences and to obtain a chronological picture of the individual use histories. The goal of the narrative interview technique is to obtain an account of a sequence of past events (Küsters, 2009). Thereby, the organization and structuring are entirely left to the interviewee. Since the interviewer does not interrupt the narrative, the interview technique helps to avoid common biases, such as social desirability, patterns of interaction in the interview, issues related to wording and placement of questions, and topics and terminology brought in by the interviewer (Küsters, 2009). The narrative interview is an especially suitable technique to address our research question for two main reasons: First, the narrative interview offers an approach which dispenses with any interviewer interference that exceeds the necessary amount. This helps discovering the user goals, technology features, related affordances, and behavioral outcomes the interviewees really used or encountered by avoiding answers and topics only triggered by the interview situation that did not have any importance for the individual use history. Second, the technique allowed us to obtain processual, sequential information with story-like character regarding the individual use histories. This was particularly important in order to understand how WAT use, affordance actualization, and behavioral outcomes unfold over time.

3.1 Data Collection

We interviewed twenty-five WAT users who were based in Switzerland. With a market penetration of 7.8 percent in 2019, Switzerland is one of the most advanced markets for wearables in Europe (Statista, 2019a). All interviews were conducted between September 2017 and July 2018. We chose to focus our analysis on users of devices by Fitbit and Apple – two of the largest providers of wearable devices worldwide (Statista, 2019b) – which share similarities regarding the activity tracking feature, for example, having a strong focus on everyday use as compared to dedicated sports tracking devices and incorporate a myriad of features related to physical activity.

Using purposive sampling, we included interviewees that met the following inclusion criterion (Miles and Huberman, 1994): all interviewees were actual intermediate to long-term WAT users (i.e., past the trial phase). All of our twenty-five interviewees had used their WATs for more than six months and some even for several years. Within this inclusion criterion, we sought maximum variation in demographics (i.e., gender, age, profession) allowing us to identify shared patterns across diverse individuals. The first interviewees were recruited through the authors' personal networks, and snowball sampling was applied to recruit additional interviewees (Miles and Huberman, 1994).

Alias	Age	Gender	Occupation	Months used	Device	User type
INT1	57	M	Managing director	12-24	Fitbit	Problem-solver
INT2	33	M	Computer scientist	> 24	Apple	Self-observer
INT3	36	F	Software developer	6-12	Fitbit	Performer
INT4	24	F	Computer scientist	> 24	Apple	Self-observer
INT5	40	M	Controller	> 24	Apple	Self-observer
INT6	24	F	Student	> 24	Apple	Dataficionado
INT7	22	F	Student	12-24	Fitbit	Performer
INT8	22	M	Student	> 24	Apple	Self-observer
INT9	53	F	Dental assistant	> 24	Apple	Dataficionado
INT10	41	M	Engineer	> 24	Fitbit	Dataficionado
INT11	60	M	Bank employee	> 24	Apple	Performer
INT12	49	F	Administrative employee	> 24	Fitbit	Performer
INT13	56	F	Administrative employee	> 24	Apple	Problem-solver
INT14	32	F	Business engineer	> 24	Fitbit	Dataficionado
INT15	46	M	IT employee	12-24	Apple	Self-observer
INT16	56	M	Computer scientist	> 24	Fitbit	Problem-solver
INT17	64	M	Computer scientist	> 24	Fitbit	Problem-solver
INT18	29	F	Media planner	12-24	Fitbit	Problem-solver
INT19	27	M	Auditor	12-24	Apple	Performer
INT20	26	M	PhD student	6-12	Fitbit	Dataficionado
INT21	27	F	Legal secretary	12-24	Fitbit	Performer
INT22	32	M	Engineer	6-12	Fitbit	Dataficionado
INT23	21	F	Student	6-12	Fitbit	Self-observer
INT24	32	F	Secretary	> 24	Fitbit	Performer
INT25	31	M	Account manager	> 24	Apple	Self-observer

Table 1. Sample characteristics

In line with the narrative interview technique, we did not use an interview guideline (Küsters, 2009) but a pre-formulated stimulus to impel interviewees' storytelling: "Please tell me the story of your activity tracker, from the moment you got it until today." After the interviewees finished their narratives (without interruption), we took up the topics the interviewees mentioned in their narratives to trigger additional accounts. Only after exhausting all narratives did we bring up other potentially important topics or concepts that had not been mentioned, such as goals and behavioral changes. All interviews were held in person, and interviewees were ensured anonymity and confidentiality in the statements they made during the interview. The variation in the duration and elaborateness of the narratives is reflected in the variation in the depth and length of the interviews, which lasted an average of 48 minutes and ranged from 26 to 83 minutes. The recorded interviews were transcribed in the participants' native language (i.e., German, Swiss German dialect, or English). Data were processed by native German and fluent English speakers. The quotations presented in this paper were either given in English or translated into English.

Our sample consists of twelve female and thirteen male students and professional whose ages ranged from twenty-one to sixty-four years. All interviewees used their WATs in their day-to-day lives, not only for specific activities. The rich narratives allowed us to reach considerable depth in the data from our twenty-five participants and to reach saturation to the extent to which the data instantiated previously determined conceptual categories (Saunders et al., 2018). Based on our data, we found a variety of features, uses, actualized affordances, and behavioral outcomes in the interviews. Table 1 presents an overview of the study's participants, including the types of users, into which we delve more deeply later in the manuscript.

3.2 Data Analysis

Our data analysis broadly followed the five-step process suggested by Leidner et al. (2018). This process is of particular help when linking technology uses, affordances, and outcomes and relating them to types of users. Since the aim of our research is to determine how the affordances WATs provide shape behavioral outcomes, we considered this process to be appropriate. The data was coded and analyzed by the first and second authors in an interpretive fashion, involving close interaction and multiple iterations.

In the first iteration, open coding of the transcripts was conducted to extract the main narrative threads and events from the individual use histories, separate them from more minor recounts, we and identify the features of WATs. In the second iteration, we coded the behavioral outcomes of using the WATs that the interviewees described. For this purpose, we used Oinas-Kukkonen's (2013) conceptualization of behavioral changes, so we coded for behavior change, compliance change, and remaining with the status quo—

the last for users who did not change their behavioral patterns. While compliance change marks a momentary action performed to comply with system requests, behavior change refers to a sustainable and pervasive shift in behavioral patterns or even routines that exceed the system's requests (Oinas-Kukkonen, 2013). Third, we coded for affordances: We began by extracting the direct uses of WAT features, separating them from the affordances, or action potentials, as Leidner et al. (2018) suggested. Next, we identified the affordances that the interviewees had actualized. For example, while "check level of physical activity (e.g., number of steps)" was a direct use of the WAT's activity-tracking feature, it afforded "working toward short-term behavioral goals." This step was highly iterative, involving close interaction and frequent discussion of individual instances among the authors to demarcate the concepts and arrive at a common interpretation. In the fourth step, we linked the WATs' features, affordances, and outcomes as abstracted representations of the dominant narrative threads found in the interviews, starting from the WATs' features, how the interviewees used them, what action potentials were realized, and which outcomes were brought about. Using one comment from the interviews, we can illustrate how we coded our data. The comment reads: "*The Fitbit gives me a good overview. Usually, when running uphill, my heart rate was skyrocketing, like up to 190 or so. My Fitbit helped me monitor that and to stay in a good range so I am not constantly reaching my peak heart rate. It let me configure a pulse range so I was able to monitor how I was performing when exercising. After some time, I also came to realize that cycling was much better for me than running if I wanted to work on my endurance*" (INT24). The feature the interviewee refers to is the pulse/heart rate tracker, which she used to check her heart rate during training and to set a pulse range she wanted to maintain while exercising. The quotation reveals that she arrived at a compliance change as she adjusted the intensity of her workout based on the moment-to-moment feedback from the WAT. Connecting this outcome with her direct use of the feature, we found that the WAT enabled her to train in a pre-defined pulse range and to observe her body's functions. In the fifth step, we turned back to the data, coding for the users' characteristics and goals. Based on the primary user goals, we identified four types of users: problem-solvers, performers, dataficionados, and self-observers. The features each of these types used, the affordances they actualized, and the behavioral outcomes they enjoyed differed.

The coding process was first applied to the interviews with Fitbit users and then to Apple users to see whether affordance actualization and behavioral outcomes differed. Since we found no differences, we combined the groups and present the findings together. The similar findings for the two groups may be traced to our analyses' having decomposed the two kinds of WATs to their features, which are similar.

4 Results

Our analysis reveals several strands, starting from WATs' features, individuals' uses of these features, and actualized affordances, leading to different behavioral outcomes for different types of users. We found six features, each of which had a distinctive use. Based on how these features were used, users actualized certain affordances, which can be grouped roughly into two categories: learning affordances, which are cognitive in nature, and behavior-focused affordances, which are behavioral in nature. Learning affordances allow users to acquire knowledge about a certain behavior by observing or reviewing one's own activity, developing awareness of one's activity levels, ranking one's performance, observing one's physical functions, increasing one's body-mindedness, understanding one's sleep patterns and quality, and assessing one's nutritional behaviors. On the other hand, behavior-focused affordances, which are more explicit in proposing behavioral actions, are often associated with goal attainment and so are more directly to be linked to the execution of a particular behavior. Behavior-focused affordances include working toward short-term behavioral goals, training in one's optimal pulse range, competing with others, and obtaining awareness of ideal behavior. Proceeding from these affordances, we observed three behavioral outcomes: 1) behavior change, referring to a substantial change in behavioral patterns and routines; 2) compliance change, which is a momentary change in behavior motivated by following a specific cue; and 3) remaining with the status quo, which suggests that existing behavioral patterns remained. These behavioral outcomes differed based on WATs' features, actualized affordances, and the type of user (i.e., problem-solvers, performers, dataficionados, and self-observers).

The following sub-sections detail the results of our analysis and structure them by type of user. Table 2 provides a comprehensive overview of the WATs' features used, the uses of those features, the affordances that users actualized, and the behavioral outcomes. The empty cells under behavioral outcomes by user type indicate that a particular strand was not associated with that type of user at all.

The presentation of our findings is structured along types of users. In addition to illustrating the strands—WATs' features, individual uses of features, actualized affordances, and behavioral outcome—we also detail the individual types of users.

WATs' features	Direct uses of features	Actualized affordances	Behavioral outcomes by type of user			
			PS	***P***	***D***	***SO***
Activity tracker	• Check level of physical activity (e.g., number of steps) • Set personal behavioral goals • Check status of goal attainment	• Working toward short-term behavioral goals (B) • Observing one's own activity (L) • Reviewing one's own activity (L) • Developing awareness of one's activity level (L)	BC	BC, R	R	CC
Challenge feature	• Invite others • Connect with others • Join challenge • Look at rankings	• Competing with others (B) • Ranking own performance (L)	-	R	-	CC
Pulse / heartrate tracker	• Check pulse / heartrate • Set target pulse range	• Observing one's own physical function (L) • Training in one's optimal pulse range (B)	-	CC, R	R	-
Sleep tracker	• Record sleep stages • Set smart sleep alarm	• Understanding one's sleep patterns and quality (L)	R	BC	R	R
Nutrition tracker	• Enter food / drink intake	• Assessing nutritional behavior (L)	-	-	R	CC
Reminders	• Receive reminders	• Obtaining awareness of ideal behavior (B) • Increasing one's body-mindedness (L)	-	CC	CC	CC

PS = Problem-solvers; P = Performers; D = Dataficionados; SO = Self-observers; BC = Behavior change; CC = Compliance change; R = Remaining with the status quo; (L) = Learning affordances; (B) = Behavior-focused affordances

Table 2. WAT Features, Use, Actualized Affordances, and Behavioral Outcomes

4.1 Problem-Solvers

The problem-solver is a WAT user whose main characteristic is a health issue or health-related dissatisfaction. These problems vary in severity, ranging from complaints about minor weight issues to diabetes or chronic cardiac disease. Before beginning to use a WAT, problem-solvers have low activity levels and are not prone to engaging in any kind of sports activity. They regard using a WAT as a way to tackle their health problem and regain control. They perceive WATs as a control device that mediates and translates between users and their bodies, offering users insights and ways to resolve issues. Problem-solvers have good reasons to change their existing patterns of action and take up the target behaviors, even though some might not be highly motivated to do so. Problem-solvers' focus lies on the activity-tracking features, including the step-counter and daily or weekly goals that the WAT imposes on them. They rarely use other features in a sustained way. One problem-solver with frequent weight fluctuations describes the WAT as motivator to get the issue under control by observing his or her patterns of activity:

> *I was very motivated, I have to admit. I tend to have weight fluctuations at times and, for me, that was a new trigger to pull myself together and control myself more closely: What are you doing where? –INT13*

Against the backdrop of problem-solvers' goals, WATs' material properties allowed these users to use their WATs in such a way that could lead to fundamental changes in behavior. Using WATs afforded gaining awareness and being proposed behavior-focused solutions to problem-solvers. Since they are not initially knowledgeable about their own health, activity levels, or how to approach their health issues, WATs allow them to observe and review their behaviors by, for example, directly comparing their behaviors to an established benchmark. A problem-solver who had suffered a heart attack describes how the WAT allowed him to set daily step goals and afforded progress toward meeting these goals:

> *I had a heart attack last year, In rehab, I learned that the only thing you can do to avoid a second one is to be more active. Some tests revealed that my heart was doing better than expected because I had started moving [prior to the heart attack] and I thought I should do even more. I raised my daily [step] goal to 15,000 after I had repeatedly reached 10,000. My way to work was too short, so I started making a detour along the river, so I am on the move for 1.5 hours.* —INT17

Positive effects in the form of improved health parameters, well-being, or positive feedback from others led problem-solvers to be in an upward spiral, becoming even more motivated and willing to throw over old habits and sometimes to alter routines fundamentally. A diabetic problem-solver recounts how improved parameters in a medical examination confirmed the value of the new routines:

> *At some point during a visit to the physician–I see my physician every three or four months because of my diabetes–critical values like blood sugar and weight had decreased. I thought, 'Well, then, [pursuing my daily step goals] is probably not wrong after all.' At the bottom of my heart, of course, I had known it for a long time: Move and you will feel better! Actually, that's quite simple, but [the WAT] was the perfect way to remind me of it. —INT1*

4.2 Performers

The performers are an active and sporty user group in whose lives physical activity plays a significant role. In sports, but also in other aspects of life, they are driven by performance and high ambitions. Thus, in the context of WAT use, performance improvements and self-optimization with the help of data are central. Their primary motivation to use WATs is to keep track of their personal development and performance improvements. The technology has an array of features for performance-oriented users. Besides intensively using several features of activity tracking, including sports tracking, they are the only group to use heartrate tracking. They also used the challenge feature, sleep tracking, and reminders, although less than they did the other factors. A performer describes reaching and stretching for personal goals enabled by the WAT as critical:

> *[I always check] how much I have done, so I always reach my goals or set new goals. I'm that kind of person: I get bored quickly and I always have to have new goals, heavier weights, longer distances, or the same distance at a faster pace. I always try to outdo myself. —INT21*

Given the performers' distinct focus on goals, they also actualized learning affordances, which allowed them to review and assess their behaviors. Such affordances work for some users as a "conscience" that gave them reason to feel either self-confirmation or guilt. These users actualized more behavior-focused affordances where they suspected a potential for optimization, such as when users used heartrate monitoring to optimize training and accelerate personal development:

> *The watch is always checking my pulse, and I can check it directly on my wrist, but what is interesting about it is that, if I know exactly in which pulse range I am burning the most fat, then I can configure that on the Apple Watch and during training to check whether I am within the pulse range. That's absolutely brilliant; that's really great. I always use it [for sports activities]. Also, when I am riding my e-bike, it*

> *indicates whether I am within the fat-burning range. After training, I can always review whether I was within the range in which I want to train. —INT11*

Behavior change occurred for this group when it was necessary for self-optimizing. However, when these users saw their existing behaviors as desirable and potentially leading to performance improvements, they retained their existing behavioral patterns:

> *It's not that I am going for extra runs because of [the WAT] but that I will walk for one or two stops, when I have to wait for the tram to arrive. Once, I was in Basel in the evening and I would have had to wait for the tram for 25 minutes or so, so I just walked home instead of standing there waiting. But I think I would have done that anyway, not only because of the Fitbit but because I just don't like to stand around waiting—I'd rather walk—but it is helping me to see these things. At the train station, for example, I am now taking the stairs instead of the escalator. I've already got around 2,500 [steps] and around seven flights now and I've only just gotten up. —INT21*

These users actualized affordances related to goal attainment, but they were not in the foreground, as they goals turned out to be easily reached, so they contributed mainly to feelings of self-confirmation. One performer joyfully describes using the WAT's challenge feature, which offers self-confirmation but is not a cue to adjust behavior:

> *I am still syncing the counter, still measuring myself, controlling myself, and I am still happy when I end up top of the list. In the meantime, we are six competitors, and I think we are going to keep that up for a while. —INT12*

Many performers temporarily put the WAT down to circumvent feedback if they anticipate that the feedback will be negative. This behavior supports the conjecture that some performance-oriented users use their WATs as a self-confirmation device, serving as an ego push. A performer describes a pattern of temporary discontinuance in stressful periods to silence the WAT's role as "conscience":

> *When I am stressed and cannot get out, this is frustrating and it is pulling me down because I realize what I have not achieved. If I know in advance that it is going to be a stressful phase, I will put [the WAT] aside because I don't want to be constantly reminded of what I have not achieved. —INT3*

4.3 Dataficionados

Dataficionados are enthusiastic about technology and curious, and they take pleasure in trying out new gadgets. They particularly like data, figures, and statistics, so using WATs serves the primary goal of quantifying themselves. Dataficionados are not particularly motivated to perform any kind of target behavior or to change their existing behavioral patterns. Instead, their interaction with WATs is largely restricted to the passive use of the activity- and sleep-tracking features, which serve as self-measurement tools. Dataficionados also use and sometimes react to reminders and track their heart rate and nutrition. One dataficionado describes in a delighted way how generating data and self-quantifying lie at the heart of his or her WAT use:

> *I guess the reason I like things like this is that I am a bit obsessive about quantification of these kind of health things and tracking statistics. I'd say that was the main reason I got it; I like looking at these charts that pop up every day. I've also got one of the scales that syncs up to it. —INT20*

Against the backdrop of dataficionados' self-quantification goal, they predominantly actualize learning affordances by observing their behavior in a neutral way, without drawing inferences regarding ideal behavior. The neutral observation of behaviors, together with not viewing their performance in light of WAT-set goals, make it easy and convenient for dataficionados to retain their behavioral patterns. Two dataficionados describe monitoring their physical activity for the sake of quantification alone, without adjusting their behavior as a result:

> *I am using the training function, which detects movements. I really like that. I am mainly doing interval training and functional training, and that's being recorded. I find it nice that it lets you see how much you have done, when, where, and at what temperature. —INT6*
>
> *I clearly see it when I am working in my home office. It has a huge impact on my steps, and it eventually gives me a guilty conscience, but it does not motivate me to go outside again if I have only 9,000 steps in the evening. I don't do that. —INT14*

4.4 Self-Observers

Self-observers are typically inactive in their work lives, with varying activity levels for their leisure time, ranging from inactive to sporty. They are primarily interested in a variety of smart watch features, not only activity tracking, leading to the purchase of more sophisticated wearable devices. Their motivation to make changes to their behavioral patterns tends to be weak; they prefer to use their WATs to gain insights into their behaviors and functioning. The goal of observing themselves leads to the use of a wide array of WAT features, including activity tracking, the challenge feature, sleep tracking, nutrition tracking, and reminders. An inactive self-observer describes how step-counting and goals help balance his activities:

To me, the step goal and checking whether I am generally active enough is very important. As a computer scientist, I also have a bit of a work-related problem, as I am sitting a lot. If I haven't done anything for an entire week, I start to feel sluggish and then I immediately have to change something. —INT2

Self-observers actualize learning and behavior-focused affordances their WATs provide. While using their WATs, they are confronted with their behavioral insufficiencies, which weakens their motivation to change. A self-observer describes how the WAT could show that he should be more active:

In the beginning, it was shocking, I saw that I was only walking 2 km or so, which is quite miserable. This motivated me to walk the stairs instead of using the elevator. It really had a strong influence on me because it showed me in a simple way how badly I was actually doing. I came to realize that I had to be more active. —INT4

After realizing that their behavior is not necessarily ideal, the behavior-focused affordances, including working toward a WAT-imposed goals, helped the self-observers make behavioral improvements actionable and feasible without having to take up entirely new behavioral patterns or routines. Thus, self-observers show a strong tendency to comply with the behaviors cued by the WAT even though they do not have a preliminary motivation to change. A self-observer describes the small adjustments he made to everyday routines to be compliant with the WAT-imposed goals:

I think once an hour you should be moving around. If you don't do that, you'll get a little reminder ten minutes before an hour has passed. It's a little reminder that you should move, which I often get at the office and I use as an occasion to go to the toilet or grab a glass of water or something like that–not always, but every now and then.... In the office, quite often I've been sitting there for two hours and really haven't been doing anything, that is, I haven't been moving. —INT5

5 Discussion and Implications

This study investigates the affordances and behavioral outcomes of WAT use; more specifically, we identify the action potentials several types of WAT users realize that lead to changes in behavior, acts of compliance, or remaining with existing behavioral patterns. Based on narrative interviews with twenty-five long-term users of WATs, we found various affordances provided by WATs that these users had actualized, which fall into two broad categories: learning affordances and behavior-focused affordances. These actualized affordances can lead to substantial changes in behavioral patterns (i.e., behavior change), simple adjustments in behavior to comply with technology cues (i.e., compliance change), or remaining with the (behavioral) status quo. These strands differ depending on the users' goals and characteristics, which we summarized as types of users based on their goals and motivations for use. We contribute to WAT research by presenting the first study to link WATs' material features to behavior change using the affordance concept as a theoretical lens. Our results show that, even when users have established highly sustainable use patterns (i.e., after several years of use), their physical behavior may still be unaffected. Therefore, we posit that the conceptual separation of WAT use and behavior change is central to analyzing and explaining either of them. We also show that whether behavioral change takes place and at what magnitude depend on the set of affordances actualized, which depends on the type of user (i.e., the user's goals).

Based on our analysis, we identify two key sets of propositions that relate to how WATs enable behavioral outcomes. First, our findings suggest that users' goals are one of the key determinants of differences in behavioral outcomes. Previous studies in the context of health and physical activity have highlighted the importance of users' goals and, drawing on the concept of motivational affordances, they have looked into the role of user goal orientation and motivation to explain the use of self-tracking technology's features (e.g., Rockmann and Gewald, 2019; Stragier et al., 2018) and benefits (Rockmann and Maier, 2019). Adopting a similar perspective, James et al. (2019) showed how exercise goals drive the use of features and how such use influences users' well-being. Other studies have focused on the fit between users' characteristics and the design of motivational feedback, showing that users' goals and motivations lead to the appreciation or rejection of various classes of feedback (Hamari et al., 2018; Hassan et al., 2019). While these related works provide substantiation for our notion of users' goal configurations, our study goes farther in showing how the use of features–which are determined by users' goals–allow users to actualize specific affordances and realize behavioral outcomes. Hence, the four types of users identified in our study are characterized by distinct goal configurations, which affect the behavioral outcomes and offer an explanation for why the use of the same feature leads to behavioral outcomes that differ from user to user. Users who have clear behavioral goals tend to change their behaviors more fundamentally, while users without such goals or only vague and malleable goals tend to retain their existing behavioral patterns or just comply with WATs' cues. This finding is in line with goal-setting theory, which posits that goals affect outcomes to the extent to which they shape motivation and effort toward goal attainment (Locke and Latham, 2002).

> **Proposition 1a**: Problem-solvers and performers are prone to show a behavior change.
>
> **Proposition 1b**: Dataficionados are prone to remain with the status quo.
>
> **Proposition 1c**: Self-observers are prone to show a compliance change.

Second, we identified two classes of actualized affordances—which identification helps to explain the functioning of the individual affordances users actualize—linking technology use and behavioral outcomes. These classes are learning affordances, which are cognitive in nature in that they create learning experiences for users, and behavior-focused affordances, which are more direct in proposing action potentials on a behavioral level and which often have the attainment of certain goals at their core. Users' behavioral outcomes depend on the class to which the actualized affordances belong, as users who actualize only the learning affordances have a tendency not to change their behaviors, while users who also actualize behavior-focused affordances tend to change their behaviors.

> **Proposition 2a**: If only learning affordances are actualized, users are prone to remain with the status quo.
>
> **Proposition 2b**: If behavior-focused affordances are actualized, users are prone to show a compliance or behavior change.

5.1 Implications for WAT Research

Our results offer explanations for other studies' varying results regarding WATs' ability to change behavior. For example, Slootmaker et al. (2009) and West et al. (2016) did not find that WATs had significant effects on behavioral outcomes using samples of office workers and undergraduate students, respectively. Knowing that behavior change predominantly occurs with problem-solvers and performers, we might explain the absence of evidence for behavior change in terms of the sample composition (i.e., overrepresentation of dataficionados and self-observers). Conversely, Barwais et al.'s (2013) presented evidence (albeit weak) for WATs' ability to induce behavior change; however, the short intervention period of four weeks allowed for only limited conclusions about behavior change because the change's sustainability was not measured. This problem is also reflected in Jakicic et al. (2016), which found supporting evidence of WATs' effectiveness but also indicated that the behavioral patterns were not sustained over the entire study period of twenty-four months.

Our findings have several implications for WAT research. First, our results suggest that researchers should identify the goals and basic motivations that their study participants pursue by using WATs. Second, researchers who use WATs devices that are designed for experimental purposes or commercially available WATs should consider which affordances the devices—or, more specifically, which of its features—may be useful to which groups of users. This consideration can be of particular importance in assessments of the affordances that users can actualize to influence their behavioral outcomes. Third, studies have measured the behavioral outcomes of WATs' use in terms of changes in physical activity, sedentary time, nutritional intake, and body weight. However, we suggest a more nuanced view that differentiates between a fundamental change in routine (i.e., behavior change) from simple acts of complying with technology cues (i.e., compliance change), as both outcomes can be valuable in improving health. Fourth, we propose that longer study periods are needed to assess the devices' effectiveness over the long term.

5.2 Implications for Designing WATs

Our results have several implications for the design of WATs. First, research that has taken a design perspective has predominantly dealt with technology affordances as requirements and with opportunities in terms of what is feasible from a technical perspective (e.g., Benbunan-Fich, 2018). However, by taking the perspective of affordances, our study shows that, even though most of the devices our participants use offer a bouquet of potential affordances, users actualized only a few of them. Therefore, WAT designers must find a better balance between technically possible affordances and affordances that users actually perceive as useful, understand, and realize. Second, depending on which of the two broad categories of affordances a feature offers, users may be hindered from arriving at particular sets of outcomes. A feature that offers only learning affordances might be less powerful in inducing behavioral outcomes since users have to come up with ideas for concrete actions themselves. This relationship can be observed with the sleep tracker, a purely awareness-creating feature that does not propose remediating suggestions for users. If users seek to change the behaviors the features track, the technology leaves them alone to find ways to realize it. This observation offers an explanation for the number of users who retain the status quo (e.g., do not change their bedtime routine despite using the sleep-tracking feature). Third, our study supports the importance of users' goals in determining which affordances users are actualizing and which outcomes they are reaching (Leidner et al., 2018), which is why users' goals should be considered when designing WATs. Inquiring about users' goals and basic motivations during a WAT's setup process may help WAT providers to tailor intervention content more precisely to the characteristics and interests of the individual users. Fourth, whether the WAT's use was sustained, long-term, or regular is an improper measure of success. All of our interview participants were continuous, long-term users of WATs, and yet we found evidence of differing behavioral outcomes (i.e., compliance change vs. remaining with the status quo vs. behavior change). Therefore, use statistics lack the power to explain WATs' behavioral effects. To assess a WAT's success in terms of inducing behavioral change, WAT providers should interview or observe users in addition to running analytics algorithms on their use data.

6 Limitations and Further Research

Despite the careful design of our research approach, our findings are subject to limitations. First, we cannot claim that our account of affordances is exhaustive, since we included only WATs by Apple and Fitbit in our analysis. Considering other devices, especially devices with stronger positioning in sports and more sophisticated sports-tracking features (e.g., training intensity, blood oxygen saturation, lactate threshold) that serve other user goals might yield other sets of affordances. Therefore, future research should study other use cases to obtain a more comprehensive picture of the actualized affordances of WATs. Second, the generalizability of the findings may be limited by the selection of participants in the study, who were all based in Switzerland. A follow-up study that takes other cultural contexts into account could determine whether the findings hold in other countries. Third, factors other than affordance actualization might jointly determine the behavioral outcomes of WAT use, so further research may investigate such factors in detail. Beyond that, future research efforts should test the propositions derived from our analysis empirically.

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Research Paper 6:
"The Generative Mechanisms Behind Technology-Enabled Changes in Health Behavior"

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The Generative Mechanisms Behind Technology-Enabled Changes in Health Behavior

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Abstract

Wearables are used to help motivate individuals to trade their unhealthful behaviors for beneficial ones, thereby preventing the diseases of affluence, which are caused by a sedentary lifestyle. However, inconclusive study results regarding the effectiveness of wearables raise questions about the outcomes of using wearables. Research on the topic paints an ambiguous picture regarding the support wearables offer users in performing beneficial health-related behaviors, leaving the underlying mechanisms of wearable use and its outcomes unexplained. We seek to fill this gap in the literature by means of a critical realist study based on thirty narrative interviews with long-term users of wearables. By identifying seven generative mechanisms that drive users' interactions with wearables and the subsequent cognitive and behavioral outcomes of that use, we answer the research question concerning how and why users' interactions with wearables can facilitate positive behavioral and cognitive outcomes. The study makes several contributions to theory and practice.

Keywords: Wearable, Health, Behavior Change, Generative Mechanism, Critical Realism.

1 Introduction

According to the World Health Organization (WHO, 2019), physical inactivity has become one of the most important factors in mortality worldwide, so supporting individuals in adopting a healthful lifestyle and preventing the diseases that are due to sedentary lifestyles is of vital societal importance. With the advancement of mobile and sensor technology, wearables have become a popular way to motivate physical movement. Wearables are electronic computing devices that are worn on the body and use sensor technology to collect and transmit data on the user's vital statistics and activities (Fox and Connolly, 2018; Mettler and Wulf, 2019). Using data analytics, wearables can identify potentially unhealthful behaviors and provide triggers to change them. Moreover, they can motivate users by setting goals or providing opportunities to compare their activities with those of peers. Because of their ready availability and ease of use, wearables have been ascribed the potential to alter human behavior in a predetermined way (Oinas-Kukkonen and Harjumaa, 2009), thereby fostering a more healthful lifestyle (Khalil and Abdallah, 2013).

However, wearables seem to be lagging behind that potential. High abandonment rates (Ledger and McCaffrey, 2014) and unclear effects on health outcomes (e.g., Jakicic et al., 2016; West et al. 2016) raise the question concerning whether and how wearables help users change health-related behaviors. Although information systems (IS) researchers have generated rich insights into the adoption (e.g., Fox and Connolly, 2018) and continuous use of wearables (e.g., Prasopoulou, 2017; Mettler and Wulf, 2019), studies that have investigated the cognitive and behavioral outcomes of using wearables remain scarce, and those that do address this topic have painted an ambiguous picture. Multiple scholars have suggested that wearables can support and empower users in performing beneficial behaviors, but they can also exert negative influences on users' affective-cognitive and behavioral responses (e.g., feelings of surveillance and guilt, detrimental effects to psychological well-being, decreased self-efficacy, and non-adherence to cues) (cf. James et al., 2019; de Moya and Pallud, 2020; Rieder et al., 2021). In other words, little is known about the processes and underlying mechanisms that are active in wearable use that generate observable responses.

We investigate the underlying mechanisms that explain *how* and *why* cognitive and behavioral outcomes emerge over time. Developing an empirically grounded understanding of what drives the outcomes of wearable use will complement and extend previous scholarly work on the use and effectiveness of wearables. Therefore, we pose the research question: *How and why does wearable use enable behavioral and cognitive outcomes?*

Adopting a critical realist ontology, we address our research question by identifying the generative mechanisms—referring to causal power—that generate use behaviors, as well as the consequent cognitive and behavioral outcomes. To derive the generative mechanisms, we conducted narrative interviews with thirty long-term users of wearables who provided in-depth insights into their use histories and their behavioral and cognitive outcomes.

Our research makes several contributions to research and practice. First, it extends the literature on persuasive health technology by presenting a nuanced picture regarding wearables' potential to improve health-related behaviors. Second, by identifying the generative mechanisms that result in behavioral or cognitive outcomes, we provide a possible explanation for why previous research has led to ambiguous findings on the outcomes of wearable use. Third, our study provides scholars with a step-by-step approach to identifying generative mechanisms at an individual level. Finally, Wearable providers and application developers can also benefit from such knowledge in their efforts to improve their devices and applications.

2 Background

2.1 Wearables for Health Behavior Change

Advances in mobile and sensor technologies have given rise to wearable IS—or simply "wearables" (Prasopoulou, 2017). A popular area of application is that of promoting healthful behaviors. Wearables are often designed with the goal of altering users' health-related behaviors by means of behavior-change techniques like self-monitoring, rewards, and social comparison (cf. Fogg, 2003; Oinas-Kukkonen and Harjumaa, 2009). Wearables are composed of physical and digital artifacts (Benbunan-Fich, 2019). In the physical sphere, sensors are interwoven into objects (e.g., wristbands, clothing) that are worn on the body, as opposed to being carried around, thereby allowing body functions like heart rate, acceleration, and sleep to be monitored and measured (Mettler and Wulf, 2019). In the digital sphere, the sensor data is paired with data analytics and machine learning applications, which create aggregations and display information to the user, either directly via wearable interfaces or using accompanying software programs on smartphones or computers (Benbunan-Fich, 2019). Given their ready availability and ease of use, wearables are ideal means to deliver persuasive content to improve health outcomes like increased physical activity and healthful diets (de Moya and Pallud, 2020).

However, research that has investigated the outcomes and health effects of using wearables remains scarce. While much of IS research on wearables has covered issues like adoption (e.g., Fox and Connolly, 2018), use, and continuous engagement (e.g., Prasopoulou, 2017;

Mettler and Wulf, 2019), only a handful of studies have sought to capture the outcomes. A notable exception is Ogbanufe and Gerhart's (2020) study of smart watches, which has highlighted both cognitive and behavioral outcomes. They found that the degree to which the smart watch was part of the user's identity was associated with more advanced ways of using it and that such a strong position in relations to the user's identity was associated with exploring new ways to employ devices to improve individual performance. However, their study focused on smart watches and their broad range of features (e.g., text messages, calendar), so the use of health-related features and the effect on health behaviors were not at the center of the study.

Focusing on the cognitive and emotional effects of wearable use, de Moya and Pallud (2020) found that wearables can leave users feeling both empowered by enabling them to improve themselves, and disempowered because of the feeling of constant surveillance and judgment. Similarly, Rieder et al.'s (2021) qualitative study found a dual influence of wearables such that contextual factors determine the effects wearables have on users' perceptions of self-efficacy and on their subsequent performance of health behaviors, creating inconsistent response patterns. Inconsistency in behavioral outcomes has been emphasized in a number of experimental studies from the medical and nutritional sciences. (For a comprehensive review, see Brickwood et al. (2019).) Even with the optimism about technologies' capacity to increase physical activity, reduce sedentary periods, and increase caloric expenditure, skepticism appears with regard to how well the effects can be sustained over time (e.g., Jakicic et al., 2016). Focusing on fitness technology, including mobile and wearable devices, James et al. (2019) found complex relationships between users' type of motivation (i.e., regulation) and users' psychological well-being. While users with a tendency toward more autonomous motivation types as well as amotivation obtained well-being outcomes, a negative relationship with wellness outcomes was observed with less self-determined users (ibid.).

Given these ambiguous, and highly complex relationships between wearable use and its outcomes, we seek to shed light on the underlying mechanisms that drive users' interactions with wearables and the subsequent behavioral and cognitive outcomes. Thus, we expect to provide explanations for the individual patterns in using wearables and the reason that some users have desirable behavioral outcomes while others do not.

2.2 Generative Mechanisms in the Critical Realist Ontology

Our goal of determining why some wearable users achieve positive behavioral changes and others do not requires that we take an approach that will help us identify the underlying mechanisms by which wearable use and the consequent behavioral and cognitive changes take place. With the concept of generative mechanisms—a form of causal power—at hand, we employ a critical realist ontology (Bhaskar, 2008) to look beyond the surface for the mechanisms that drive individual outcomes and patterns of use.

The value of the critical realist philosophy for IS research has gained increasing attention (e.g., Dobson et al., 2013; Henfridsson and Bygstad, 2013; McGrath, 2013; Mingers, 2004; Smith, 2006; Volkoff et al., 2007; Smith, 2010; Zachariadis et al., 2013). Critical realism, a philosophical paradigm developed by British philosopher Roy Bhaskar, offers an alternative to empiricism and idealism. Central to critical realism is the *stratified ontology*: The critical realist presupposes a real world beyond human experience and influence that consists of events that have empirically manifested at the surface (i.e., the empirical) stratum. The stratum subjacent to the surface stratum encompasses events that may have happened, although they have not been or cannot be experienced by human senses. Below that is the stratum of the real, which consists of the deep structures of the world (i.e., generative mechanisms) that may only become actual or empirical through the events they cause at the surface (Bhaskar, 2008). While human agents may well interfere with events at the surface, the generative mechanisms of the domain of the real lie beyond human influence. Generative mechanisms, which are the causal power in the critical realist philosophy, refer to the way of acting of things; they hold the potential to cause changes and phenomena that may become manifest at the empirical level. In regarding the real world as an open system, where no constant conjunctions prevail, critical realism rejects determinism and the possibility of deducing consequent events, thus emphasizing multicausality (i.e., an event may be caused by multiple factors) and multifinality (i.e., a factor may cause multiple outcomes). Hence, in pursuit of explanations, the critical realist seeks to identify the one explanation that best explains the mechanism that generate the events X, Y. For example, Big Bang theories hypothesize various mechanisms that have operated since the Big Bang event. One such mechanism is a constant rate of expansion of the universe.

IS research has published two types of articles that use the critical realist paradigm: methods articles and empirical articles. Wynn and Williams' (2012) guidance for researchers in conducting critical realist case studies in IS highlighted the importance of using *judgmental rationality*—that is, comparing the explanatory power of alternative theories—in critical realism, while Bygstad et al.'s (2016) framework introduced how generative mechanism could be identified through affordances. Empirical articles have used the critical realist ontology in several ways. For example, Bygstad (2010) conducted a critical realist case study of Norwegian airlines to explain how an information infrastructure provides generative mechanisms for innovation, Henfridsson and Bygstad (2013) used critical realism in infrastructure research and identified three generative mechanisms for explaining how digital infrastructures evolve, and Williams and Karahanna (2013) identified two generative mechanisms of coordination processes. Our study employs a critical realist perspective to explain an IS phenomenon, so it falls into the category of empirical articles. While previous empirical articles have focused on organizational IS and so have revealed macro-level mechanisms, we seek to identify the generative mechanisms that are present in individual users of individual IS.

3 Methodology

3.1 Epistemological Stance

Applying the critical realist philosophy of science has several implications for our epistemological stance and methodological approach. Given the premise of a stratified ontology, capturing the world's stratification is the purpose of science. Science is regarded as both the social activity of producing knowledge and the resulting knowledge that is constructed by human agents (Bhaskar, 2008). In this regard, critical realism employs an epistemology similar to the interpretivist. Another implication is that, since the deep structure level of the world cannot be observed per se—that is, it reveals itself to human senses only through the empirical patterns it generates—imaginative steps must be employed, thus justifying induction (Bhaskar, 2008). Bhaskar referred to this process as "retrodiction" (2008, p. 118), which describes making conjectures about the causal explanation that drives the emergence of a pattern of events. Finally, to be able to find abstract generative mechanisms from empirical patterns inductively, we need data that can produce insights into the sequential patterns in which events occur along the process of wearable use, into the behavioral outcomes, and into users' emotional and cognitive processes. Given these requirements, we follow Klein and Myers (1999) in using narrative data to address our research question.

3.2 Data Collection

We interviewed thirty long-term wearable users based in Switzerland, whose market penetration of 7.8 percent in 2019 makes it one of the most advanced markets for wearables in Europe (Statista, 2019). Since our focus is on the use of wearable devices' health-promoting features, we included users of wearables that were dedicated to health and/or sports (e.g., Fitbit, Polar) and users of general-purpose devices that were employed for health purposes (e.g., Apple, Huawei). Despite slight differences in the features of different brands, all devices' feature sets included goal-setting, monitoring and evaluating physical activity, and sending reminders. Because behavior change unfolds over time (Prochaska and Velicer, 1997), we needed to capture a longer use period. After six months, users were likely to have passed the initial trial period, a period that is often not representative of long-term technology use. Using purposive sampling (Miles and Huberman, 1994), we included only long-term users of wearables who had used their devices for at least six months. Given this criterion, we sought maximum variation in demographics (age, gender, occupation), purposes of use (e.g., addressing medical conditions, optimizing sports performance, gathering data), and types of devices (lifestyle and sports). We used the narrative interview technique as our method of inquiry, following Küsters' (2009) guidelines. Since this technique dispenses with an interview guideline, we used a pre-formulated stimulus to kindle the interviewees' storytelling: "Please tell me the story of your wearable, from the moment you got it until today." Questions were asked only once the interviewees had finished their narratives, when we took up topics that the interviewees had mentioned in their initial narratives to impel additional accounts.

The interviews were held in person or via Skype video call. The data were collected by multiple researchers to ensure that differences in the data arose from the interviewees and their individual contexts rather than from interviewer bias (Wallendorf and Belk, 1989). The interviewees were assured anonymity, and the interviews ranged from nineteen to eighty-seven minutes (excluding preliminary talk and instructions). The interviews were held in the interviewees' native languages of German or Swiss German dialect and were transcribed verbatim. Native German speakers processed the interviews so we could use the original transcripts and quotations for data analysis, but the quotations presented in this paper are translated into English.

Our sample (Table 1) consists of twelve women and eighteen men from twenty-one to sixty-three years of age, including students, professionals, and one retiree. The slight overrepresentation of men is in line with the wearable adoption statistics (Statista, 2019). More than half of the interviewees had used their wearables for more than two years, while the remainder had used their wearables for six months to two years. The interviewees used devices of multiple brands but predominantly Fitbit, Garmin, Polar, and Apple. While most interviewees used their devices every day and even at night, some wore them only when they engaged in sports. Our interviewees described various motivations for adopting and using their wearables, including pursuing specific health-related or sports goals (e.g., running a marathon, losing weight); getting an overview of their levels of physical activity, sleep or other vital parameters; or using its smart features for reasons unrelated to health. Our sample included a diverse range of activity levels and health conditions, from users who were chronically ill (e.g., diabetes, coronary diseases, overweight) to inactive to highly active users, some of whom regularly participated in sports competitions as amateur athletes (e.g., middle-distance runner, triathlete, ultramarathoner). Rich, in-depth narratives from thirty interviewees was considered sufficient for data-gathering, as by the time we completed these interviews, we had observed thematic saturation (Faulkner and Trotter, 2017).

Full sample	#	Gender	#	Devices used[1]	#
N	30	Women	12	Fitbit	12
Occupation	**#**	Men	18	Garmin	12
Student	5	**Use duration**	**#**	Polar	8
Professional	24	6-12 months	5	Apple	6
Retired	1	13-24 months	8	Other[2]	5
		> 24 months	17		

[1] Some interviewees had used multiple devices.
[2] Other brands included devices by Jawbone (2), Misit (1), Suunto (1), and Huawei (1).

Table 1. Characteristics of Interviewees

3.3 Data Analysis

Since our research seeks the generative mechanisms that drive *individual's* use processes and outcomes related to wearables, a category of individual IS (Baskerville, 2011), we followed Bhaskar's (2008) original four-step process of "explanation formation" (p. 125): decomposition, redescription, retrodiction, and elimination. We describe each step of our data analysis and illustrate it with the example from interviewee #3, a 40-year-old male project manager and Garmin-user whom we chose at random for use in presenting our approach.

1. Decomposition: The purpose of decomposition is to resolve a complex event into its components so causal analysis is possible. For this step, we resolved the interviewees' individual narratives into their components: events, agents, conditions, and outcomes (Table 2).

Events in a narrative refer to changes in the domain of the empirical (and actual) and result either from the actions of agents or what happens to things. We extracted the kernel events related to wearable use from our data. *Outcomes* are events that show, in our case, behavioral and cognitive consequences like change and impact. Outcomes are events, too, so we coded them as events, but we also coded them separately as outcomes for later use. *Agents* in critical realism are entities that have the power to interfere with empirical phenomena, that is, to induce changes. For our research, we operationalized agents as entities who interfere with events or sequences of events. While some interviews featured multiple agents (e.g., friends, medical doctors), in others only the users themselves acted as agents. Even wearables themselves may become agents when individuals perceive them as mentors or leaders. Finally, *conditions* refer to the structures of systems that shape the actions of generative mechanisms and the empirical patterns they produce. We operationalized conditions as structures that affect wearable use, which was often users' personal or professional contexts. Table 2 provides an overview of the elements of the components to illustrate our approach.

Events and <u>Outcomes</u>	• Consistently monitors day-to-day activities • Feels enabled to pursue and reach goals • Reviews training data and tracks progress • Adjusts training intensity based on heart rate feedback • Makes small adjustments to daily activities to be in line with the wearable's guidelines • Gains awareness of daily activity patterns	• Takes up training for a half marathon • Has no knowledge about how to train • Buys a wearable to support his training • Gets a training schedule from Garmin • Follows schedule • Tracks runs • Monitors heart rate • Explores day-to-day features
Agents	• User (e.g., male, age 40) • Wearable (several, including Suunto watch)	• Friends • Work colleagues
Conditions	• Office job (sedentary) • Engages in sports multiple times per week • No training expertise, especially not in running	• Different wearable devices with different feature sets • Marathon is on his "bucket list"

Table 2. Exemplary Decomposition of a Narrative (based on Interviewee #3)

2. Redescription: The redescription step redescribes the complex event (i.e., wearable use history) at the individual level to facilitate theorizing about the mechanisms at work. For this step, we reassembled the component events into the sequence of events, which involved reconstructing the chronological and causal sequence because the narrative structure of the interviews did not necessarily reflect the causal sequence (interviewees skipping back and forth between themes, adding more detailed accounts, etc.). To obtain a holistic picture of the causal links inherent in the data, we drew the causal sequence of events for each interviewee as a visual pattern (Figure 1).

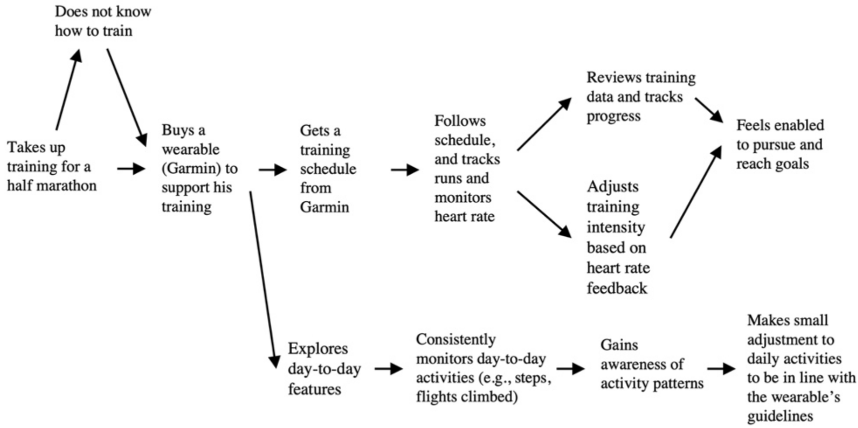

Figure 1. Exemplary Sequence of Events (based on Interviewee #3)

3. Retrodiction: The retrodiction step involves backward chaining from consequent to antecedent events and inductively and creatively making conjectures about causal explanations that may have produced the events. In line with Bhaskar (2008), we sought a plurality of possible explanations, so this step involved frequent discussion and several iterations with the co-authors for plausibility checks (Wallendorf and Belk, 1989). Table 3 illustrates the process for Interviewee 3.

Candidate Mechanism 1: ***Confirmation***	• The user seeks the wearable's confirmation during his running training. The heart rate feedback is one of the features that provides confirmation, and he adjusts his training intensity to get that confirmation. • Following a training schedule can be regarded as seeking confirmation. This is supported by his lacking training expertise, giving him a reason to seek approval to see if he is training correctly. • He makes adjustments to his activities based on awareness that constant monitoring of day-to-day activity raises to his behaviors, so he seeks confirmation from the wearable. He adjusts his behavior to be in line with the benchmark and to avoid disconfirmation.

Candidate Mechanism 2: ***Self-Improvement***	• The user has ambitious, self-set sports goals and uses several features to achieve them (e.g., heart rate feedback, reviewing training, purchasing and following a training schedule). • He initially buys the wearable to pursue their goal of running a half marathon to tick it off of his bucket list, which indicates the his self-motivation. • As he explores other uses the wearable affords, he takes up monitoring his day-to-day activities, which makes him aware that his activity is not always ideal. Wanting to be a better version of himself, not only in the area of sports, he makes small adjustments to his activities.

Table 3. Exemplary Candidate Mechanisms (based on Interviewee #3)

4. Elimination: The elimination step involves extracting from a set of candidate mechanisms the generative mechanism(s) that caused a complex event. We conducted the elimination on two levels: within and across individual interviews. To ensure plausibility, we systematically reviewed and discussed the elimination process among the co-authors (Wallendorf and Belk, 1989). For the within-check, we turned back to the component events and the data and found disconfirming instances that did not match the candidate mechanisms. In the example of Interviewee #3, we found three disconfirming instances for the confirmation mechanism, while there was no difficulty explaining the reasons for emergence of the self-improvement mechanism: 1) constantly increasing his goals, 2) using day-to-day features without initially intending to, and 3) using the wearable to track his training progress retrospectively. Consequently, we eliminated the confirmation mechanism.

For the across-interviewee check, we compared interviews to see whether the same mechanism was really at work. This step was needed especially when similar empirical patterns were traced back to the working of different generative mechanisms or where the same generative mechanism caused varying empirical patterns. For example, after the first few instances, the self-documentation and self-knowledge mechanisms were difficult to tell apart because the empirical patterns they caused were similar at first sight. Only after adding more data were we able to differentiate the patterns the generative mechanisms caused (i.e., a detached way of collecting and viewing the data for entertainment vs. observing and processing information about oneself). Hence, this iterative step of jumping back and forth between interviewees and between generative mechanisms helped to identify how the mechanisms were acting. Following this inductive process, we identified seven generative mechanisms that allowed us to explain the phenomena related to wearable use as our interviewees experienced it.

4 Results

Our data analysis revealed seven generative mechanisms that drove wearable use and users' cognitive and behavioral outcomes. The generative mechanisms that tend to change behaviors are self-improvement, self-determination, and confirmation. These three mechanisms not only have the power to impel the continuous use of wearables but also foster users' alteration of their offline health behaviors related to wearable use. The mechanisms that tend to generate purely cognitive outcomes are self-documentation, self-knowledge, exploration, and social relatedness. While individual use patterns driven by these four generative mechanisms are continuous, the mechanisms do not cause changes in users' physical behaviors. Instead, we found an array of cognitive outcomes related to these generative mechanisms, such as learning, entertainment, and feelings of social belonging.

4.1 Generative Mechanisms Related to Behavior Change

Self-Improvement Mechanism: The self-improvement mechanism describes an internal drive to be better. The activity of the mechanism entails a strong behavior change tendency on the empirical level since individuals must make adjustments to their behaviors to get better. The self-improvement mechanism is closely related to users' intrinsic motivation and to achievements that create intrinsic rewards, so external motivators (e.g., seeking social recognition) play only a minor part, if any. On the empirical level, users in whom the self-improvement mechanism is active tend to set challenging goals and gradually increase them to become better versions of themselves. To them, objectively measured performance and achievement are central indicators of success. While wearables do not play a central role in goal-setting itself, users extensively employ them as guides, commitment devices, and reward machines.

For example, in providing users with training schedules and specific guiding cues during training, wearables supported users in working toward attaining self-set goals. Users also reported that, by creating transparency through social features and historical data, their wearables provided additional areas in which to strive for self-optimization. When using social features (e.g., leaderboard), users could work on improving their performance relative to that of others, whereas using historical data helped them improve relative to their past selves. While these features were not at the center of users' reasons for using wearables, they helped them stay committed to their goals and provided them with rewards that gave them a sense of achievement. One interviewee described how she used wearables to pursue her ever-increasing goals and used the wearables' monitoring features to guide her training and review her progress toward attaining her goals:

When I started running a year ago, it was important to have a GPS tracker so I wouldn't have to carry my phone, so I got one that tracked my routes and also monitored my heart rate and rotations. Then, last summer, I took up training for triathlon and realized there was even better stuff for that purpose, especially for swimming, and that's how I got the [Garmin] Fenix 5S. It can do a lot more. For example, I can get these performance parameters like VO2-Max or navigation for mountaineering, and I can connect it to my training plan for the Ironman. Since I am training for seven hours of physical performance, I need to monitor my performance and view my development and how I improve. It might be that sometimes I feel like a slave to the watch: Today, I had planned on a slow jog, 21 kilometers, below 158 bpm, but then at 11 kilometers, the watch was at 5 percent [battery], so I had to speed up to get it recorded. (Female nurse, age 33, Garmin-user)

Self-determination Mechanism: The self-determination mechanism relates to the drive for intentional and effective action. With wearable users, we found that the activity of this mechanism is related to a strong change tendency involving users' autonomous steering of health behaviors and attitudinal shifts. On the empirical level, the self-determination mechanism is reflected in users' desire to take matters into their own hands and exercise influence and control to shape certain aspects of their lives. This mechanism was typically found with wearables users who faced some sort of subjective pain point that they either knew about before (e.g., certain health issues) or were made aware of by the wearable (e.g., low activity levels, weight gain). Wearables provided them with the ability to tackle their issues. Typically, we saw users shifting from the position of a patient who is passively receiving information about her condition from the environment to a proactive agent who co-creates her environment as a consequence of intensified self-determination. One interviewee spoke of incidents that created a pivot point for him to change unhealthful behaviors and routines. In response, he started to wear his wearable consistently and to monitor and assess all his activities. He described how the wearable helped him recognize how behaviors and well-being were linked. In working to overcome detrimental habits, he built awareness about the consequences of his behaviors, took up a more mindful lifestyle, and fostered new routines:

I've been wearing [the wearable] day and night for half a year now, mainly because I gained a lot of weight over a short period. There were two moments last year that made me think. First, I was at a wedding where the groom's father was sick with lung cancer; that's when I thought "you can't keep smoking like a chimney." Second, there was this soccer game that I played last summer when I suddenly felt dizzy and fainted. Of course, I could have said, "It was hot, you didn't drink enough," but I'd also gained a lot of weight. I think it's the combination of causes that made me *change. ... And since then, I've been tracking how active I am and how much sleep I get. I try to reach the 10k steps per day by going for walks right after lunch. I also registered at a gym. Once a month or so, I enter what I ate during the day so I can see whether I am below or above my calorie expenditure, so every once in a while, I do say no to a beer or a dinner that I've been invited to. This is also reflected in my sleep quality; when I've been drinking, I feel less recovered. I don't think that I fundamentally changed my behavior, but I am definitely trying to be more mindful of myself and my body and be more aware of my behaviors. (Male financial analyst, age 35, Garmin-user)*

Confirmation Mechanism: The confirmation mechanism describes the drive to obtain approval of one's own actions and behaviors from external points of reference. Since only behaviors that are in line with the reference get approval, wearable users tend to change their behaviors, but only to the extent that will help them avoid disconfirmation. Users with whom the confirmation mechanism was dominant reported seeking approval about whether their condition or behaviors were adhering to reference points that were considered acceptable standards on the empirical level. For example, they wanted to assess whether their activity levels were in accordance with the prescriptions issued by the WHO or whether their resting heart rate was in an acceptable range for their age. Wearable devices acted as a mediator between users and external reference points, facilitating and allowing for more granular variance analyses and proactively notifying users about the actions that were necessary to adhere to the standards. Thus, wearables had especially strong agency.

Closely related to the action of the confirmation mechanism was users' response by seeking strict compliance with the wearables' goals, cues, and requests, rather than constant improvement and attaining above-average statistics. Interviewees who reported having difficulty in self-assessing their physical activity found a wearable that would support them in evaluating their behaviors relative to the wearable (i.e., steps per day). Seeking adherence to and approval by the device, they adjusted behaviors in their everyday lives and reacted to explicit cues from the wearable. A few users, driven by this mechanism, reported feeling pressure to adhere to the wearable's cues and experiencing negative emotions like frustration and guilt when they did not comply with the wearable. As a consequence, users sought to adhere to the cues to avoid these negative experiences. One interviewee stated that she experienced disconfirmation and intense negative emotions when she did not or could not comply with the wearable's requests, which was then reflected in her activity data:

I liked the idea of counting steps because I think people tend to have a distorted idea of their activities. I sometimes thought that I'd been very active even though I just spent the entire day at the office, so I wanted transparency about what is happening, transparency about my health—not necessarily the result, but where I stand. That was the main motivator. It was important to me, when I was on the road and doing sports, to learn what I had really done. I have my step goal at 10k and I really try to achieve it. There are times when I purposely go for a walk, mainly on weekends. If I get to choose between walking around the block or sitting in front of the TV, I will always choose the walk. I was surprised how important the data became to me and how strongly it encouraged me in what I was doing, though there was a time when I didn't reach it and that really annoyed me. I was going through a stressful period and didn't have the time to go out, and that frustrated me and got me down because the device always showed me what I had not achieved. I don't want to have to view the goals I did not reach because I couldn't change it. (Female developer, age 36, Fitbit-user)

4.2 Generative Mechanisms Related to Cognitive Outcomes

Self-documentation Mechanism: The self-documentation mechanism refers to the drive to capture one's own actions. The objective of the behaviors related to this mechanism is to produce and view the documentation itself for the purpose of entertainment and personally leaving a trace, so pursuing offline health behaviors was not associated with this mechanism. On the empirical level, users with whom the self-documentation mechanism was active sought to record their actions comprehensively over longer periods of time to produce a diary of their activities. By providing many tracking features and connectivity with other applications, wearables facilitate the process of documentation and make viewing the recordings appealing to users. Accordingly, the outcomes caused by the self-documentation mechanism resemble entertainment in viewing one's collection, rather than cognitive processing of the information obtained. In wearable use, self-documentation was often related to meticulous monitoring of various activities and was comparatively little related to (re-)viewing the data in a detached manner. One interviewee talked about his use of exercise-tracking to be able to obtain a representation of his runs in the form of an entry to a map. Despite the importance he assigned to being monitored and to viewing the recordings frequently, he was detached from the data. Instead of relating the metrics to himself and his exercise-related behavior, he used the recordings to browse through the places in the world he had been to and the marathons and trainings he had completed:

I got a Polar watch for my birthday in 2009. Technologically, it was very limited, but I liked it because I could download my running data and project my routes onto Google Earth. Sometimes they disintegrated Google Earth, so I bought a Garmin

> *because they use a better map. I use it only for running. I am often abroad for business, and whenever I go running, I take my watch with me. That's so cool when you can trace where you've been and the places you've passed by, and also the kilometers, pace, and altitude. That's, well, informative, though certainly not vitally important. … So since 2009, the coolest thing for me is the map, seeing the route and getting data about distance, altitude, and calorie burn. The device does not influence my training. I don't need the device to tell me what to do; I set my goals myself. (Male medical doctor, age 63, Garmin-user)*

Self-knowledge Mechanism: The self-knowledge mechanism relates to the drive to obtain knowledge, particularly knowledge about oneself. It predominantly gives rise to cognitive outcomes like awareness and learning, leaving behavioral patterns unaffected. On the empirical level, users in whom the self-knowledge mechanism is active want to observe and learn about their own behaviors and functioning, so they employ the wearable as a magnifier that makes visible behavior patterns and conditions that they had not been able to observe otherwise. They observe themselves by monitoring and reviewing their activities with the help of the wearable. Then they use the new knowledge about themselves to adjust their convictions and even the formation of normative judgment regarding their behaviors. One interviewee, who bought an Apple Watch without intending to self-track any health parameters, provided a good example of the self-knowledge mechanism in reporting how he took up using self-tracking features when he decided to lose weight. Wanting to learn about his own activity patterns, he started tracking all of his activities and appreciating the data for helping him gain awareness and becoming more mindful about his behaviors:

> *When I decided that I had to lose some weight, I felt that I needed to get a feeling for how active I was, so I started counting my steps. After some time, I started monitoring any activity when I went for a walk, went hiking, or rode a bicycle. The positive effect was that it helped me get interested in how active I was; it started to matter to me. I don't actively follow the activity goals because I automatically reach 80 to 90 percent on weekdays. Of course, I try to be mindful of it, but I don't follow it very strictly, so it is more about observing and compensating on weekends to meet the goals on average. But I wouldn't rule out that the watch indirectly influences me just by being on my wrist and that I probably stand and move more often than before. … To me, it is an unobtrusive, easy-to-handle companion that adds some sort of systematic awareness. It's not that I wouldn't go for walks if I didn't have a wearable, but it makes me more aware of whether it was 4, 5, or 12 kilometers. (Male IT employee, age 46, Apple-user)*

Exploration Mechanism: The exploration mechanism describes the drive to scout and play around with unfamiliar things. Even though exploring an unfamiliar thing may yield the discovery of new or unexpected potential for actions, no tendency to change behavior is associated with this mechanism since users explore for exploration's sake. Instead, this playful form of technology interaction has entertainment outcomes. With wearables, the exploration mechanism is manifested on the empirical level in users' curious and enthusiastic interactions with the technology and engagement with the data output. The exploration mechanism gave rise to diverse use behaviors, depending on the object users wanted to explore. Users who explored what the wearable enabled them to do in general had comparatively fuzzy use patterns that involved periodic, on-and-off use of a wide range of features. Others' explorations were directed to a specific activity and the related data output, which led to a more in-depth use of a reduced set of features. One interviewee, who had been using his wearable to record his mountain bike tours for more than two years, spoke about his excitement and enjoyment in reviewing his tour data, and his disappointment once when he forgot to monitor the tour. Not being interested in exploring anything but the tours, he did not engage with any other features. It was clear that exploring was followed by entertainment (i.e., viewing the tour video) but not by conclusions about behaviors or behavioral change:

> *I've been looking for a device to record my mountain bike tours. ... There are several features, and I could easily record my entire life, but I just don't care; I don't know what to do with most of the data. It is fantastic for sports though; you can record your entire tour and make a video of it, complete with images and music—just a little compilation. It is interesting to see that here is where I climbed a hill—12 percent incline, pulse at 180 beats per minute—and to realize that this is where I was breathing heavily. Sometimes I forget to activate the tracking mode. That was the most annoying thing, if I've been taking a break and paused the watch and then forgot to reactivate it. After getting home and uploading my data, I would see that half of the tour was not recorded, and the data was missing. That really upset me. (Male engineer, age 41, Polar-user)*

Social-relatedness Mechanism: The social relatedness mechanism describes the drive to feel connected with and accepted by social groups. The mechanism gives rise to predominantly cognitive outcome of feeling related. On the empirical level, users seek contact with social groups, along with their acceptance and approval so they do not feel isolated. For this purpose, users may employ wearables to signal their belonging to a certain social group or even to contact members of the group by using the wearable's social features. For example, users may get a running watch to signal that they belong to the group of runners or may use social features to underscore their status as the “sporty” person in a social group. While the use of social features was also present with other generative mechanisms, the social relatedness mechanism’s pattern of use for realizing social belonging outcomes by connecting with others, such as through competitions, was unique. One interviewee, who was highly oriented toward others’ reception of her behaviors, talked about her extensive use of social features. Using competitions against her real-life friends over the app, she sought to be at the top of the ranking, frequently checking her status and gearing her physical activity level to win. Her own performance in light of the (lower) performance of others strengthened her status within the group and nurtured her motivation:

> *When my friend told me about the characteristics of her activity tracker, I was on fire and ordered one the same day. I connected with a lot of friends. Three times a day or so, I checked what the others were doing, where I was in the ranking, and whether I had reached 10k steps. I have to admit that I like competing against others; I always have. I participated in a few competitions in the past. We’re six competitors now, and I am still really joyful if I am at the top, though maybe I’ve been checking with lower frequency lately. ... But comparing myself to others and realizing that only 30 minutes of training would win me a rank motivates me to do it. There’s some sort of obligation toward myself. (Female administrative employee, age 49, Fitbit-user)*

5 Discussion

This research set out to investigate how and why wearable use gives rise to certain behavioral and cognitive outcomes and adopted Bhaskar’s (2008) critical realist perspective to investigate this socio-technical phenomenon (Wynn and Williams, 2012). The concept of generative mechanisms as they relate to critical realism gave us a way to explain how individuals reach certain behavioral and cognitive outcomes. In contrast to prior research, our study captures wearable-enabled change by scrutinizing the sequence of events that unfold over time and identifying their underlying generative mechanisms. Using this approach, we found multiple empirical patterns that connect wearable use with its outcomes and revealed seven generative mechanisms that drive wearable use and its outcomes. We divided these causal mechanisms into two categories related to their outcomes: mechanisms that cause a change in users’ offline behaviors (i.e., self-improvement, self-determination, confirmation) and mechanisms that give rise to cognitive outcomes but cause no change in physical behaviors (i.e., self-documentation, self-knowledge, exploration, social relatedness). Through these mechanisms, we can explain how and why wearable use enables some individuals to change their behavior, but not others.

Our study makes several contributions to the literature on wearables and to IS research that addresses phenomena at the individual level. First, our study presents a nuanced picture of wearables' potential to change individuals' health-related behavior. Our findings from users who were driven by the self-improvement, self-determination, and confirmation mechanisms confirm the persuasive potential of wearables, as users who were driven by these generative mechanisms reacted positively to suggestions from their devices and engaged in the proposed activities. However, users who were driven by self-improvement and self-determination were empowered by the wearable to gain knowledge and take control of their own health and/or performance (de Moya and Pallud, 2020). Consequently, these users had a tendency to fundamentally change their routines, while users who were driven by confirmation merely complied with the device's suggestions (Oinas-Kukkonen, 2013). We found that behavioral changes occurred even when users had no intention of changing their behavior. The device triggered their motivation by showing them a discrepancy between their actual behaviors and the behaviors the wearable suggested (Bhattacharya et al., 2018). On the other hand, users who were driven by the self-documentation, self-knowledge, exploration, and social relatedness mechanisms refused the wearable's persuasive potential, as they were not interested in or responsive to its persuasive features. For example, users who were driven by the exploration and social relatedness mechanisms did not use their wearables to improve their fitness but to explore its technical capabilities or reach a feeling of social belonging. However, rather than changing their behavior, these users achieved cognitive outcomes like learning and entertainment, which they perceived as valuable and which drove their long-term wearable use. This outcome is in some ways similar to the concept of semiotic-aesthetic wearable use that Pols et al. (2019) identified. This finding highlights that behavior change should not be seen as the only desirable outcome of wearable use.

Second, our findings enrich the understanding of the nature of the generative mechanisms that shape wearable use and these mechanisms' behavioral and cognitive outcomes. While IS research on wearables has gained traction in recent years, little attention has been paid to the outcomes. Medical and nutritional research that has found inconsistent results regarding the health effects of wearables, have not provided insights into how and why such outcomes occur (cf. Brickwood et al., 2019). By finding that several generative mechanisms are active in wearable use, we provide a possible explanation for previous research's having observed varying outcomes and results (James et al., 2019b). Previous studies have conducted sampling based on cross-sectional characteristics like age and medical conditions (e.g., Naslund et al., 2016), but these characteristics say little about the generative mechanisms that generate outcomes and drive individuals' use of wearables. In particular, we found that such cross-sectional criteria as users' activity levels, health condition, age, and use periods, along with the type of device they use were distributed across generative mechanisms and outcomes. For example, the self-improvement mechanism was present with semi-professional athletes but also with inactive individuals who sought to optimize their general activity levels by using a wearable. In addition, the level of the devices' sophistication varied: Sophisticated sports watches were not only found with the self-improvement mechanism but also with the self-documentation and exploration mechanisms. Even rubber bands have been used by individuals driven by several mechanisms, including self-improvement and self-documentation. Therefore, researchers who seek to assess wearables' effectiveness are advised to take into consideration the mechanisms that are active with study participants in shaping their use behavior.

Third, our study has an implication for IS research that seeks to apply a critical realist perspective at the individual level. Previous IS studies have employed a critical realist stance to examine technology-enabled changes in organizations and have adapted the methodology to identify generative mechanisms on the macro level (e.g., Wynn and Williams, 2012). To the best of our knowledge, no IS study has used the critical realistic ontology to investigate the causal powers behind the use of individual IS (cf. Baskerville, 2011). Against this backdrop, our study makes a methodological contribution by providing a practical, step-by-step approach to deriving generative mechanisms based on Bhaskar's (2008) abstract guideline. This contribution enables other scholars to apply our approach to their own endeavors.

Fourth, practitioners gain valuable insights for the design of wearables. As our results demonstrate, not all users seek behavior change despite using the devices over long periods of time. For example, some users use the devices only to track their activities and interact with the data or to learn something new about themselves. Such users tend to perceive persuasive messages as interruptions, causing them to disable features or put the device away. This finding indicates that wearable design that focuses solely on behavior change is not always optimal. Instead, the devices should be designed in a way that cater to a wider variety of uses. Wearables should not impose goals (e.g., frequent movement) for but assist users in achieving their individual goals. To fulfill the promise of highly personalized computing (Rapp and Cena, 2016), wearables must offer individualized options.

6 Limitations and Further Research

The present research is subject to limitations that pave the way for future studies. First, while narrative interviews allowed us to gain in-depth insights into individuals' use histories, the presence of memory bias should be considered. Because we interviewed long-term users of wearables, the insights our study may provide with respect to short-term use and abandonment are limited. Future research may include individuals who have used wearables for shorter periods or discontinuous users to examine the generative mechanisms and outcomes of such use patterns. In addition, we identified generative mechanisms that explain the outcome tendencies in the context of our study (i.e., wearables), so, to expand our findings, future research could examine whether these mechanisms are also present during the use of other persuasive health technologies and the outcomes they tend to cause since the same generative mechanisms in open systems may lead to different outcomes, depending on the context (Bhaskar, 2008). Our study could also be replicated in other cultures to determine whether our results are sensitive to cultural contexts or can be generalized across countries.

A second limitation is that our study identified seven mechanisms that give rise to various behavioral and cognitive outcomes for wearable users. However, we did not focus on the patterns of interaction between generative mechanisms or the triggering conditions and events that cause the mechanisms to become actualized as empirical. Future research on the mechanism's activity patterns, including identifying any counteracting mechanisms and their interplay with the mechanisms revealed in this study, could be worthwhile.

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Research Paper 7:
"Design Blueprint for an Adaptive Persuasive Health System"

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Working Paper

Design Blueprint for an Adaptive Persuasive Health System

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Abstract

Persuasive health systems, like wearable self-tracking devices or fitness apps, are attributed great potential to improve individual health outcomes by supporting the formation of healthy habits and mitigating the risk of unhealthful behaviors, such as a sedentary lifestyle. However, users' discontinuance and inconclusive study results regarding the effectiveness to improve health behaviors dampen the hopes. Using a design science research approach, this paper aims to provide theoretical insight regarding the design of a persuasive system that has the capacity to effectively evoke long-term health behavior change. Building on the existing body of knowledge and practical challenges, a design blueprint, including design requirements, principles, and features for an adaptive persuasive health system is developed. Following the detailed elaboration of the design features, the artifact is evaluated with various actors in the health ecosystem and refined based on the feedback. Moreover, theoretical contributions and design implications are presented.

Keywords: Persuasive system, health, behavior change, blueprint, design science.

1 Introduction

With the recent developments in mobile and sensor technology, persuasive systems have gained traction in the field of health promotion. Persuasive systems are information systems (IS) designed to influence behavior in a predefined way (Fogg, 2003). Reaching a market penetration of more than 20% in the USA in 2018, wearable self-tracking devices––one of the most prominent categories of persuasive health systems—have long since reached mainstream users (Statista, 2020). In the health context, persuasive systems have been employed in various fields: to support physical activity (e.g., Fitbit) and healthy nutrition (e.g., MyFitnessPal), to observe sleep patterns (e.g., SleepScore), to foster mindfulness and psychological well-being (e.g., MoodKit), to offer specific training-support (e.g., Runtastic), and to manage chronic diseases (e.g., MyTherapy), to name a few.

The health sector, researchers, and public health institutions place considerable hope on persuasive health systems to improve individual and public health outcomes and mitigate the risks and social cost of diseases of affluence originating from a sedentary lifestyle (WHO, 2010; Gimpel et al., 2013). In reality however, articles about the high abandonment rates of persuasive health systems keep dominating the discourse (Ledger and McCaffrey, 2014) and a closer look at studies assessing the effectiveness of these technologies to improve health behaviors and outcomes are inconclusive and dampen the prospects (Brickwood et al., 2019). While persuasive health systems have been shown to be effective in boosting physical activity and caloric expenditure, and reducing sedentary periods (Barwais et al., 2013; Finkelstein et al., 2016), their capacity to improve users' physical activity levels, aerobic fitness, and body weight and body composition was not supported (e.g., Slootmaker et al., 2009; West et al., 2016). Other studies indicated positive short-term effects on behavioral outcomes, though these effects were not sustained over longer periods of time (Jakicic et al., 2016). Recently, a handful of IS studies also outlined various detrimental effects of persuasive health system use on users' emotions, i.e., increased feelings of surveillance and guilt (de Moya and Pallud, 2020), self-efficacy perceptions, and cue-adherence (Rieder et al., 2020b).

Given the discrepancy between expectations and the realities of using persuasive health systems, this research aims to provide theoretical insight on how to develop a persuasive system that is effective in evoking health behavior change. Specifically, I aim to answer the following research questions:

RQ1: What are the fundamental challenges of persuasive systems for health behavior change and what design requirements can be derived from these challenges?

RQ2: What design principles and design features to guide the development of a persuasive health system are suitable to address these design requirements?

To answer these research questions, I use a design science research (DSR) approach (Hevner et al. 2004; Peffers et al., 2007). I develop an artifact consisting of a set of design requirements, design principles, and design features and present practical tools upon which system providers may base the instantiation of a persuasive health system. Ultimately, I evaluate the artifact with different actors in the health ecosystem and refine it based on the feedback.

In generating design knowledge for persuasive health systems, I address a broad and generic problem class related to health promotion. Researchers and system providers may both benefit from the blueprint presented in this paper to guide their efforts when investigating and/or designing systems addressing specific challenges within this class of problems. Moreover, the superordinate value of more effective persuasive health systems lies in helping to improve users' health-related quality of life as well as public health outcomes.

The remainder of this paper is structured as follows. In section 2, I give an overview of the foundations of persuasive health systems. In section 3, I present the DSR methodology and my research approach. Section 4 represents the heart of the study, encompassing the design requirements, design principles, and design features. In section 5, I cover the evaluation approach and outcomes. Section 6 encompasses the discussion, including theoretical contributions and implications for practice. Finally, section 7 concludes with a discussion of the limitations of the study and avenues for future research.

2 Foundations

According the World Health Organization, non-communicable diseases represent one of the key causes of premature deaths (WHO, 2014). They include an array of so-called diseases of affluence, for example, raised blood pressure, type 2 diabetes, and overweight, that are traceable to sedentary lifestyles and unhealthy nutrition (WHO, 2019). While impairing the health-related life quality of those affected, diseases of affluence also induce significant strain on the public health system and increase the cost of healthcare and related social costs. To prevent these detrimental outcomes, public health and research efforts have therefore been directed toward health promotion. Traditionally, such behavior change interventions in the health context were initiated and mediated by health professionals. However, with the advancements of digital technology in the past two decades, especially the spread of mobile devices and sensor technology to capture human activity, a good share of these interventions was transferred to the digital sphere and is now delivered through digital channels (Kraft et al., 2009). Delivery via digital technologies holds multiple advantages, such as, lower cost of the intervention, the possibility to include personal sensor data and individualize interventions based on it, the opportunity to harness a person's social resources through incorporating social media, and the use of a wider variety of persuasion strategies (Fogg, 2003; Coughlin and Stewart, 2016; Lyons et al., 2014). IS that aim to alter users' behaviors and attitudes in predefined ways are denominated as persuasive systems (Oinas-Kukkonen and Harjumaa, 2009), since they use various persuasion strategies to induce these changes (Michie et al., 2013). Persuasive systems in the health context can come in different shapes (e.g., computer programs, mobile apps, wearable self-tracking devices) and target various health-related behaviors (e.g., physical activity, nutrition, sports, sleep, mental health, disease self-management). Prominent examples of commercially available persuasive health systems include such systems as Fitbit, MyFitnessPal, Runtastic, and MoodKit.

Some of the research investigating the use of persuasive health systems and its outcomes has attested the technology's capacity to improve different outcomes with users. In a meta-review of the effectiveness of wearable activity trackers, Brickwood et al. (2019) conclude that, overall, they can be deemed effective in increasing physical activity and caloric expenditure, and reducing sedentary periods. Also, IS studies have reported various positive effects of persuasive health systems use regarding cognitive and behavioral categories with users. For example, smartwatches were found to help users improve individual performance after profoundly exploring new ways to employ the technology (Ogbanufe and Gerhart, 2020). Moreover, wearable activity trackers were shown to empower users in enabling them to self-improve with regard to various aspects of behavior (de Moya and Pallud, 2020), and another study indicated that features of wearable lifestyle devices afforded both positive cognitive outcomes, such as learning and self-knowledge as well as improvements in behavioral outcomes, such as sports performance and increased physical activity (Rieder et al., 2020a). Moreover, persuasive health systems use was found to positively affect psychological well-being with self-determined users (James et al. 2019b).

Despite these promising prospects, the shortcomings of persuasive health systems keep dominating the discourse. Several studies questioned their capacity to improve users' physical activity levels, aerobic fitness, and body weight and body composition (e.g., Slootmaker et al., 2009; West et al., 2016). Moreover, skepticism is directed toward the sustainability of the induced behavioral changes. Jakicic et al. (2016) indicated that despite positive effects on users' weight loss at six months, the benefits were not sustained over the full study period of 24 months. In IS, research has been concerned with identifying the reasons for the high abandonment rates of persuasive health systems (e.g., Attig and Franke, 2020), emphasizing the roles of motivation loss due to negative feedback, privacy concerns, and developing obsessive tracking behaviors. Moreover, several IS studies indicated the existence of harmful effects of persuasive health system use with regard to emotional, cognitive, and behavioral outcomes. In a review of IS literature on the negative effects of gamification in health behavior change support systems, Schmidt-Kraepelin et al. (2019) identified five categories of unintended side effects, i.e., adverse motivational effects, informational noise, reduced integrity of exercise, demoralization of users, and overstepping boundaries. Moreover, examining fitness app users' continuance intentions, Rockmann (2019) found the systems' motivational affordances may harm users' perception of their competence. De Moya and Pallud (2020) demonstrated that persuasive health systems had the power to leave users disempowered as they imposed surveillance on them, which lead to feelings of guilt. Last, Rieder et al. (2020b) indicated the possibility of persuasive health system use lowering users' self-efficacy toward a health behavior and eradicating their adherence to system-cues.

This pronounced discrepancy between a technology's potential and the manifestation of its effects in reality indicates that there is a significant gap in the knowledge of how to leverage the behavior changing potential of persuasive health systems with both, researchers and practitioners. I therefore aim to provide theoretical insight and practical guidance on how to develop a persuasive system that is effective in evoking health behavior change.

3 Methodology

To address these gaps in design knowledge, I employed a DSR approach (Hevner et al., 2004; March and Smith, 1995). Design Science is a well-established research paradigm in IS and has been described as a "problem-solving paradigm" (Hevner et al., 2004, p.76) which seeks to generate knowledge about relevant problems and create practical solutions for these problems by means of designing innovative artifacts (Winter, 2008). The artifacts resulting from DSR are defined as "something that is artificial, or constructed by humans, as opposed to something that occurs naturally" (Gregor and Jones, 2007, p.313) and can take a variety of forms, such as, constructs, models, methods, and instantiated systems (Hevner et al., 2004). DSR methodologists suggest that the creation of artifacts must rely on "justificatory knowledge" (cf. Gregor and Jones, 2007) , or "kernel theory" (cf. Hevner et al., 2004) that provide a rationale for the way of working of the artifact and its component constructs.

Regarding the structure of the research process in DSR, there has been an intense ongoing discourse amongst IS scholars, resulting in a variety of different approaches (e.g., Hevner, 2007; Peffers et al., 2007; Beck et al., 2013)

My research design follows the process for conducting DSR projects proposed by Peffers et al. (2007) and was guided by the specific approach used by Meth et al. (2015). The process was initiated by an intensive literature review to help identify the problem and challenges reflected in RQ1. Based on the literature review, I developed a set of preliminary requirements for the artifact. In the object definition phase, I derived the design principles drawing on a second literature review focused on the body of knowledge and established theories. In the same phase, I identified the generic design features needed to be able to realize the principles. As part of the design features, I developed tools to facilitate the implementation of the design features. The abstract design blueprint, consisting of requirements, design principles, and features and tools was consolidated to demonstrate to and evaluate with various actors in the health ecosystem using semi-structured interviews. For this, I built on the proposal by Hevner et al. (2004) to use black box (i.e., functional) and white box (i.e., structural) perspectives for evaluating an artifact. Based on the feedback obtained in the evaluation, I refined the artifact. Due to space limitations, only the final, refined artifact is presented in this paper.

4 Designing a Persuasive System for Health Behavior Change

4.1 Developing Design Requirements

To identify key challenges based on which to develop design requirements for a persuasive system that enables changing users' health behaviors, I drew upon practical problems identified by the extant literature. In line with the definition by Meth et al. (2015), I understand design requirements as "generic requirements that any artifact instantiated from this design should meet" (p. 807). The studies used to inform the development of design requirements included research regarding persuasive systems, particularly in the context of individual health (e.g., wearable activity trackers, fitness apps), and research regarding behavior change (e.g., behavior change interventions). Besides IS journals and conferences, I included relevant outlets from other fields (e.g., medical science, computer science). Based on these articles, I conducted backward and forward search (Webster and Watson, 2002).

The first challenge is related to users' experiences in interacting with persuasive health systems that are very unique, and therefore difficult to foresee. When building persuasive systems, designers have in mind specific ways of employing the features and outcomes that may thereby be reached. However, researchers argued that users' perception and interpretation of these features and their ways of using them may differ from designers' intentions as well as between individual users (Rockmann and Gewald, 2018; Rieder et al., 2020a). In this, some features may be 'misunderstood' and their effects never become actualized. Even worse, researchers found that discrepancies between designers' and users' intent may lead to significant side effects, such as, disempowerment, feelings of pressure and guilt, as well as obsessive tracking behavior (Benbunan-Fich, 2019; De Moya and Pallud, 2020; Attig and Franke, 2020). Therefore, I derive the following design requirement:

DR1: PHS should anticipate users' unique experiences of interaction.

The second challenge arises from users' being individuals with different personalities, motivations, goals, aspirations, social contexts, and preferences. Individual factors play a major part in shaping use and response patterns. For example, research found that personality affects the way individuals react to psychological influence principles used in persuasive systems and thus determines at least partially the impact of persuasive features (Baumgart and Wiewiorra, 2016; Kaptein et al., 2015; Karppinen et al., 2018). Moreover, the lack of personalization options was criticized by researchers arguing that forcing uniform features upon users was very unlikely to result in alignment with individual motivations and goals (Bhattacharya et al., 2018; James et al., 2019a). Ultimately, researchers have noted that these individual factors are subject to changes over time, indicating that personalization endeavors that rely on one specific point in time may not capture users' individual development (Fritz et al., 2014; Kaptein et al., 2015). Hence, the second design requirement is:

DR2: PHS should be tailored to users' individual needs.

Psychological processes represent the third core challenge of persuasive health systems. While using technology, and during behavior change, individuals are subject to a variety of psychological processes and needs. The literature identified such processes and needs that are insufficiently addressed by persuasive health systems: learning, psychological needs, habit formation, and coping. Learning processes were studied from to two different angles: First, learning to use and effectively employ the technology for supporting behavioral change received little attention from system providers (James et al., 2019a). Second, a disproportionate targeting of conscious, analytic thought processes, leaving the potential of unconscious, intuitive learning untapped (Pinder et al., 2018). Moreover, persuasive health systems were found to undermine users' psychological needs to feel competent and autonomous, and thereby negatively affect intrinsic motivation (James et al., 2019a; Rockmann, 2019). Also, literature stressed the importance of habit formation for long-term changes in behavior and systems' deficiency with that regard (Karppinen et al., 2018; Nascimento et al., 2018; Rieder et al., 2019; Stepanovic et al., 2019). Last, little support was found to be offered in mitigating negative effects, for example, resistance and malicious coping behaviors (Sjöklint et al., 2015; Pinder et al., 2018). Consequently, I derive the following design requirement:

DR3: PHS should follow and support users' psychological processes.

The fourth challenge is related to constraints from and changes in the context which may pose a risk to users' willingness and ability to engage in a behavior. To ensure long-term use and improvements in health behaviors, persuasive systems must become deeply entangled in users' daily lives and environments (Karppinen et al., 2018; Stepanovic et al., 2019). In the moment in which persuasion occurs, users must be free from constraints to follow the cue (Kaptein et al., 2015). Constraints may originate from external context (e.g., weather, work-related constraints) but also from internal context (e.g., users' mood and emotions, temptations, previous habits) and undermine users' confidence and intention to do a behavior (Rieder et al., 2020b). Even though research found that users principally have the resources to overcome contextual constraints, systems fail to detect and counteract the constraints (Pinder et al., 2018; Rieder et al., 2020b). Consequently, the fourth design requirement is:

DR4: PHS should support users in overcoming contextual constraints.

The last challenge relates to persuasive health systems' digital components which must be fit to support the core purpose of changing health behavior. For this, usually various persuasion strategies are employed with varying effectiveness to evoke behavioral change. Researchers criticized the persuasive components used for a lack of theoretical grounding (Pinder et al., 2018) and for low degrees of innovation to include strategies other than the ones commonly used (Lyons et al., 2014; Karppinen et al., 2018; Xu et al., 2018). Instead, they focus on very few strategies (e.g., gamification) that are then used in overflow (Schmidt-Kraepelin et al., 2019). Commonly used strategies predominantly target the acquisition of new behaviors, leaving it to chance whether users will eventually arrive at the decision to change their behavior and offering little to no support in sustaining newly acquired behaviors (Fritz et al., 2014; Bhattacharya et al., 2018). Moreover, some of the prominent persuasion strategies (e.g., rewards, reminders, loyalty points, competition) were found to exert detrimental effects on users' motivation and willingness to perform the behaviors (cf. James et al., 2019a; Fritz et al., 2014; Nascimento et al., 2018; Liu et al., 2014). Furthermore, a dominant line of research investigated the implementation of social features in persuasive health systems and concluded that—despite being a powerful class of strategies—social support was not sufficiently harnessed (Fritz et al., 2014; Lee and Lim, 2015; Xu et al., 2018; Lehto and Oinas-Kukkonen, 2015). Thus, the fifth design requirement is:

DR5: PHS should incorporate digital components that are effective in evoking behavioral change.

4.2 Deriving Design Principles

Next, I present the design principles, which refer to the generic capabilities of an artifact fit to address the requirements (Meth et al., 2015). For this, I turned to theory and the existing body of knowledge. Two theoretical perspectives—the self-determination theory and the transtheoretical model of health behavior change—as well as insights from their research application sensitized the design of my artifact.

First, I draw on the self-determination theory (Deci and Ryan, 2008). The self-determination theory is a theory of human motivation and distinguishes types of motivation on a continuum ranging from controlled motivation to autonomous motivation. While autonomously (commonly referred to as 'intrinsically') motivated individuals act out of volition and engage in self-endorsement, individuals with controlled (or extrinsic) motivation often act in light of a contingent reward or punishment or out of approval, avoidance, or self-esteem motives. Both of these types of motivations are effective in energizing and directing action, though, autonomous motivation usually yields greater performance, long-term persistence, and psychological well-being (Ryan and Deci, 2000).

Moreover, the self-determination theory offers insights into promoting psychological well-being and effective functioning. Deci and Ryan (2000) presuppose the existence of three basic and universal psychological needs: competence, autonomy, and relatedness. Contextual factors may either satisfy or thwart the psychological needs and thereby cause differences in individuals' motivation, behaviors, and outcomes. In fact, research related to health behavior change showed that the psychological needs uphold in the health and IS context. For example, Rockmann (2019) criticized the undifferentiated implementation of gamified elements for thwarting some users' autonomy and competence needs.

Research suggests a superiority of more intrinsic regulation styles of motivation as compared to extrinsic ones, since activities performed with intrinsic motivation were found to be self-reinforcing, energizing, and creating psychological well-being (Ryan and Deci, 2000; Lally and Gardner, 2013). The type of motivation a person has critically shapes the goals and aspirations they pursue. Related to persuasive health systems, James et al. (2019a) showed that extrinsic exercise goals, such as, goals focusing on a person's body-image, were associated with significantly lower well-being from fitness technology use.

Based on this reasoning, I arrive at the first design principle, personalization, which addresses DR1, DR2, DR4, and DR5. In order to support users' self-determination, persuasive health systems must appeal to a number of individual factors, such as, motivation, goals, aspirations, and internal and external factors from users' context. On the one hand, personalization is crucial to be able to support users' psychological needs. The goal must be to enable a bit-by-bit internalization of motivation (i.e., a shift towards autonomous motivation), for instance, so users' starts seeing an activity as useful, joyful, or even adding to their identity. On the other hand, thwarting users' psychological needs must be avoided by any means. Research suggests that it is oftentimes a (situational) misfit between the intervention goals and contextual factor that cause need thwarting (cf. Rieder et al., 2020b). For preventing these situations, it is central for persuasive health systems to know the individual user and be context-sensitive. Moreover, certain persuasion strategies, for example, contingent rewards or negative performance feedback, are inherently thwarting autonomy resp. competence needs (Deci et al., 1999). Even though they may present effective strategies to extrinsically motivated users—though likely limited in sustainability—, they pose a great risk to intrinsically motivated users since they may undermine their intrinsic motivation (ibid.).

DP1: The system and the persuasion strategies are personalized to users' individual needs.

Second, I use the transtheoretical model of health behavior change (TTM). Developed by Prochaska and Velicer (1997), the TTM proposes a process view of change and has since been applied by researchers in health and related fields. They postulate that health behavior change evolves through different stages, including stages prior to the actual change in behavior. In the precontemplation stage, people tend to be uninformed about the consequences of their behaviors and therefor do not intend to change in the foreseeable future. Next, awareness is rising in the contemplation stage, causing ambivalence, culminating in the preparation stage, in which people form the intention to change and create concrete action plans. The actual change in behavior takes place in the action stage. In the maintenance stage, behavioral patterns become increasingly ingrained and easier to uphold. While in some contexts a termination stage exists in which the change process is completed, it is indicated that in some areas, like health, exercise, and nutrition, maintenance tends to be a lifelong quest. Relapse, that is, returning to previous behavioral patterns, can occur in any stage and may range from a momentary lapse to a permanent regression into preceding stages of change.

Based on the underlying assumption that behavior change is an ongoing process rather than a once-off activity, I derive the second design principle adaptivity, which is fit to address DR3, DR4, and DR5. In addition to DP1, which acknowledges users' individuality and stresses the importance for a persuasive health system to distinguish them from one another, DP2 appeals to the within-shifts associated with users' progression through the behavior change progress. Depending on the stage in the change process, persuasive health systems must provide users with matching guidance, and sets of features and techniques to offer enhanced and suitable support taking into consideration the specificities of each stage (Karppinen et al., 2018). For example, in earlier stages of change the emphasis should be on creating awareness, directing users' attention to specific behaviors, and gradually leading them to the realization of the need to change (Bhattacharya et al., 2018). In later stages, however, the focus should rather lie on creating positive reinforcements, making achievements and outcomes transparent, and counteracting relapse, for instance, using coping planning. Along with the progression through the behavior change process, users' focus, motivations, and goals but also the context may be subjected to change (Fritz et al., 2014), which represent, of course, additional factors that need to be taken into account by persuasive health systems and to which they need to adapt.

DP2: The system and persuasion strategies adapt to users' stage-specific needs.

The third design principle, sustainability, unifies both theoretical perspectives and is meant to address DR2, DR4, and DR5. The principle indicates that persuasive health systems must be designed for long-term changes rather than a high number of downloads or hypes around activities with an excessive difficulty level to be upheld by users (e.g., step challenges). The first key to achieving long-term engagement is promoting autonomous motivation, since autonomous motivation types are associated with self-endorsement, positive reinforcement, volition, and superior performance (Ryan and Deci, 2000). In this, users with a controlled motivation must be supported in achieving an internalization of the motivation regulation, while autonomously motivated users' needs must continuously be supported (and not thwarted). The second ingredient is supporting users in progressing toward the late stages of the behavior change process. Making it to the maintenance stage and receiving stage-specific support represent good prerequisite towards automation of behaviors and thus the formation of real habits (Lally et al., 2010; Lally and Gardner, 2013). Aiming for the installation of beneficial habits is a promising path toward long-term behavior change, since habits are extremely resistant to short-term constraints, shocks, and also willing attempts to be altered (Oinas-Kukkonen, 2013).

DP3: The system and persuasion strategies are designed for sustainable long-term change.

4.3 Mapping Design Principles with Design Features

Last, I give an overview of the design features the artifact has to include in order to realize the principles above. According to Meth et al. (2015) design features refer to specific ways to implement a design principle in an actual artifact. Figure 1 presents an overview of the proposed principles and how they relate to the design principles and requirements.

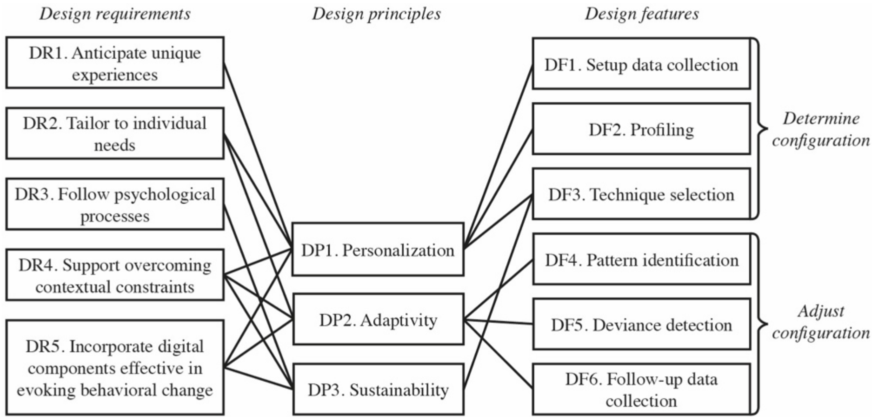

Figure 2. Design requirements, principles, and features.

The first design principle, personalization, calls for three features that enable a static configuration of the persuasive health system to the individual user. First, collecting data on the user when starting to use the system is required (DF1). Besides personal data (e.g., age, height, weight, health condition, personal circumstances), data regarding health behaviors (e.g., activity level, sports routine, known harmful behaviors) as well as a number of latent variables (e.g., goals, aspirations, motivation and motivation type, typical constraints, and the entering stage of change) are needed. Based on this information, users have to be profiled and located on the motivation/change matrix (cf. Figure 2) (DF2).

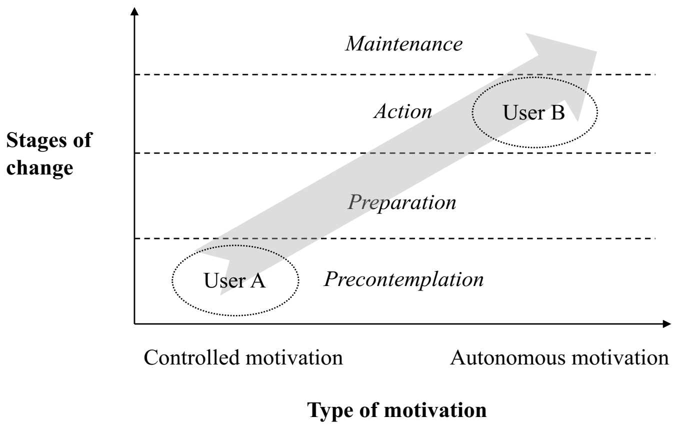

Figure 2. Motivation/change matrix with two sample scenarios.

The motivation/change matrix serves the purpose of facilitating the determination of an individual user's starting position on the 'playing field' based on their type of motivation and current stage of change. The two scenarios depicted in Figure 2 will clarify the utility of the matrix: User A may be an unathletic businessperson with a desk job in their fifties whose health is gradually deteriorating. Their family gives them a Fitbit urging them to be more active. Even though the user does not acknowledge the need to change, they adopt the persuasive health system out of politeness and start tracking their steps and calorie expenditure. In contrast, User B may be a young amateur runner whose goal is to once run a marathon. For this, they feel the need to engage in specific training and they subscribe to a training plan by Runtastic for systematic guidance. While User A enters the playing field in the precontemplation stage and controlled motivation, User B has already progressed to the action stage prior to adopting the persuasive health system and is autonomously motivated to perform the behavior. Clearly, not only the different focus and activity, but their mere starting position calls for a different configuration of the persuasion strategies that make up the system. Hence, the combination of techniques selected to persuade uses to change must be in accordance with their starting positions (DF3). There is a vast body of literature on persuasion strategies and empirical evidence on their effectiveness in different circumstances (i.e., motivation types, stages of change) (e.g., Deci et al., 1999; Michie et al. 2009; Michie et al. 2013; Lally and Gardner, 2013; Liu et al., 2014; Lee and Lim, 2015; Oinas-Kukkonen and Harjumaa, 2009). To support the selection process, in Table 1, I give an overview of the different categories of persuasion strategies1 appropriate in different stages of change resp. the associated direction.

With the design features to realize the second design principle, adaptivity, the dynamic factor is introduced to the artifact. While the respective configuration of the persuasion strategies may be suitable for a considerable amount of time, it will eventually lose its relevance as users progress through the behavior change process or as the context evolves. As indicated above, a persuasive health system's goal must be to accompany users to the top-right corner of the matrix (i.e., autonomous motivation x maintenance stage); this evolution is indicated by the grey arrow in Figure 2. Since behavior tracking lies at the core of persuasive health systems, usually a solid base of longitudinal data for each user exists and is constantly growing. Hence, patterns of interacting with and reacting to the technology can be identified and incorporated into individual data models (DF4). Depending on the kind of persuasive health system and its focus, interaction patterns may

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1 Due to space limitations, I cannot give a comprehensive list of the individual techniques associated with each stage. However, if the manuscript is accepted for publication at ECIS 2021, I shall provide an online appendix encompassing the comprehensive list. Please note that the provision of an online appendix is not possible at the time of the first submission since it would violate the double-blind review policy.

encompass such data as checking times and frequencies, features and feature activation, or social engagement. Reaction patterns include data like adherence to cues, latency of response, responding activities. The data models can then be used to detect deviations from the patterns (DR5), for example, when a user starts checking their data in the morning instead of the afternoon, stops responding to certain cues, or takes up new activities. Since, at this point, it is difficult to spot what is causing the deviance from the use pattern solely based on tracking data, new data must be collected to identify the causes (DF6). The primary purpose of DF6 is to make out whether the deviance resulted from a permanent shift in contextual factors or the user's progression in the behavior change process. As in the data collection for the setup, constructs should include personal data, data regarding health behaviors, and latent variables. A change in context is likely to require an adjustment to the settings of the intervention. For example, if a user has new working hours, which requires them to do their workouts in the evening rather than in the morning, this might require new action planning and an adjustment in the timing of cues or performance reports. Other than that, if the deviance can be traced back to a shift in the stages of change, this requires updating the configuration of the system to fit the requirements of the new stage. For example, as a user moves from the preparation stage to the action stage, they may need less behavior modeling through watching others do sports, but more assistance in action planning and rearranging their day-to-day activities to fit in a sports session.

Last, the design principle, sustainability, is addressed through the technique selection and its ongoing adjustment (DF3, introduced above) that enable persuasive health systems to accompany users for long periods and across the entire change process regardless of users' changing needs, conditions, or stage of change.

Direction, Stage	*Persuasion strategies to **afford***	*Persuasion strategies to **avoid***
Vertical: Precontemplation	Behavior modeling; consciousness-raising; sensory learning; self-monitoring	Competition; tangible, contingent, conditioned rewards or threats
Vertical: Preparation	Catalyzing decision; action planning; self-goal setting and intrinsic goal content; association; rehearsal; social support; sensory learning	Extrinsic goal content; imposed goals; competition; tangible, contingent, conditioned rewards or threats
Vertical: Action	Self-monitoring; task support; associations; complexity reduction; appreciative feedback; endorsement; coping planning; experience creation; professional support	External control and authority; imposed goals; time-based cues; social pressure; cognitive dissonance; tangible, contingent, conditioned rewards or threats

Vertical: Maintenance	Self-monitoring; cueing; social reinforcement; appreciative feedback; coping planning; professional support	External control and authority; social pressure; tangible, contingent, conditioned rewards or threats
Horizontal (i.e., internalization of regulation)	Behavior modeling; appreciative feedback; autonomy support; social support; competence support; intrinsic goal content	External control and authority; extrinsic goal content; negative emotional regulation; tangible, contingent, conditioned rewards

Table 1. Persuasion strategies associated with stages of behavior change and direction.

5 Evaluation

The evaluation served the purpose of assessing the value of the artifact, i.e., the blueprint, to different stakeholders in the health ecosystem. The goal was to obtain feedback regarding the artifact's (technical) feasibility, estimations of its acceptance, its societal value, its potential contributions to personal and public health, and its potential business value. For this, I demonstrated the artifact to representatives of four different stakeholder categories of the health ecosystem: system providers, health insurances, users, and public health institutions. This approach allowed me to obtain insights from various angles on the core objective of health promotion. I followed the technique proposed by Hevner et al. (2004) to contrast a constructive, structural (white box) with a functional (black box) perspective in evaluating an artifact. To demonstrate and evaluate the artifact, I consolidated its building blocks (i.e., design requirements, principles, features and associated tools) into a blueprint understandable to non-researchers. Depending on their perspective, the blueprint was presented to the interviewees with different stresses. While the emphasis with representatives of system providers and health insurance (i.e., white box) was on the constructive elements of the solution, that is, the features, and the modus operandi of the proposed tools and techniques, the interviews with users and representatives of public health institutions (i.e., black box) were more geared towards the underlying problems, and the acceptability and utility of the proposed solution. An overview of the interviewees and their positions/characteristics can be found in Table 2 below.

I conducted semi-structured interviews via video call. The interviews lasted between 52 and 80 minutes and were recorded and transcribed for later analysis. Most of the aspects presented in the blueprint were supported by the interviewees. Therefore, and due to space limitations, I will only provide a summary of the aspects which specifically informed the refinement of the artifact.

While generally, the challenges and associated design requirements presented received great support, PH1 emphasized the importance of personal social networks in catalyzing behavior change. In their experience, individuals with specifically strong ties to their respective communities (e.g., elderly people, immigrants) are more easily addressed and influenced through key actors in the community—an effect that may be harnessed in health interventions. Consequently, I complemented the list of individual factors in DR2 by personal social networks. Another insight was shared by SP4, who stated that in their view, context (cf. DR4) was not a restricting factor if the system was designed to “offer” a strategy given a specific set of circumstances rather than to “demand” a pre-defined behavior no matter the circumstances. While I am convinced that a situational approach is key to persuasive health systems—which is reflected in DR4, DP1, and DF5—I do think that behavior change and habit formation cannot purely rely upon “offering” approaches, but also require “demanding” elements, for example, associated with action planning. Additionally, several interviewees hinted toward the existence of technical challenges. Data discontinuity due to limited battery life, and unreliability as well as inaccuracy of measurements was mentioned as posing a major issue (SP2, SP3, U1, U2, U3). The interviewees agreed, if an intervention was relying upon faulty, incomplete or inaccurate data, this would eradicate any tailoring effort. Being a major limitation for any persuasive health system, I decided to add this aspect as a basic technical prerequisite (cf. section 6.2).

While all of the features were supported by the interviewees, I received some comments regarding details of the proposed tools that I wish to outline here. U2 criticized the plan to collect data at initial setup for potentially being regarded as disrespectful to users’ privacy. She indicated that disclosing this much—and especially personal—information would require the prior establishment of trust in the system which may take some weeks of use. Hence, I recommend system providers to incorporate greater flexibility with regard to the point in time in which the setup survey is taken by users (cf. section 6.2). Moreover, different suggestions were given to complement the list of behavior change techniques accompanying the motivation/change matrix. PH1 and SP4 indicated that incorporating the possibility to consult “real” health coaches or counselors through the system may be helpful especially for users with lower health or technology literacy. Furthermore, PH1 hinted at the fact that with the proposed techniques, learning processes are primarily cognitive in nature, whereas sensory learning approaches (e.g., visual, tactile, audible) are underrepresented. Last, SP3 argued in favor of competitive elements and tangible rewards, since in their experience, these strategies had been highly effective. While I complemented the proposed techniques by sensory learning approaches and professional support, I decided to disregard the comment on competition and rewards since such strategies directly counteract several of the design requirements and principles elaborated above.

Evaluation	*Interviewee*	*Perspective*	*Alias*
White box	Program manager health app	System provider (mobile)	SP1
	Developer health platform	System provider (mobile)	SP2
	Developer health platform	System provider (mobile)	SP3
	Mechanical engineer medtech	System provider (wearable)	SP4
	Digital customer experience manager	Health insurance	HI1
	Health promotion manager	Health insurance	HI2
Black box	User of wearable step tracker and smart tooth brush (male, 60 years, attorney at law)	User	U1
	User of wearable lifestyle tracker (female, 26 years, brand manager)	User	U2
	User of sports watch and social sharing platform for sports (male, 32 years, photographer)	User	U3
	Deputy head state department for health promotion	Public health institution	PH1
	State department for preventative and mental health	Public health institution	PH2

Table 2. Overview of interviewees.

6 Discussion

6.1 Theoretical Contribution

In the following, I will synthesize the results of my research into a conceptual design theory as proposed by Gregor and Jones (2007), which represents the key contribution of my research.

The goal of this study was to develop a design blueprint for a persuasive health system that effectively induces changes in users' health-related behaviors. The artifact is supposed to serve intervention designers of digital (scientific and commercial) behavior change interventions and system providers (e.g., of wearable self-tracking devices, physical and mental health apps) as a guideline for development and a catalog for persuasive elements to incorporate. Within the field of health, the artifact may be used in various contexts, such as, physical activity, nutrition, sports and exercise, mental well-being, and disease self-management, to improve an even greater variety of health-related behaviors.

I derived challenges from literature to define the requirements of the artifact. To meet these requirements, an artifact has to follow the design principles of personalization, adaptivity, and sustainability, which are realized in a set of functional and constructive design features. To facilitate the implementation of the design features in an actual artifact, I proposed different tools (e.g., motivation/change matrix, catalog of persuasion strategies) supporting the principled translation of the abstract blueprint into a functioning IS. I based my design requirements upon literature on persuasive systems for individual health and behavior change research and drew on the self-determination theory and TTM for deriving the design principles. The combination of these two core concepts is—despite the empirical support and general recognition of their importance—novel with regard to persuasive health systems. While several researchers have called for addressing personalization and the support of individual needs (e.g., Kaptein et al., 2015; Chatterjee et al., 2018), adaptivity to changing context and users' progression through the change process, thus far, represents an overlooked principle.

Moreover, the design features are built upon the applied research on behavior change interventions, as well as insights regarding persuasive health systems. In this, my research is based on solid scientific knowledge justifying the proposed goals, elements, processes, and tools.

Being a blueprint for the design of IS to achieve a specific outcome in the users' domain (i.e., sustainable health behavior change), the artifact presented is independent of the kinds of physical and digital components of an IS, the underlying types of data, and specific technological advancements. Hence, the artifact is highly mutable (cf. Gregor and Jones, 2007), meaning that it will not lose its relevance even if, for example, in the future, data will be collected by microsensors implanted in the human body, allowing for novel and more nuanced insights of biochemical processes which in turn allow for more fine-grained personalization of interventions. Even in such a scenario, the requirements remain valid, and the core principles of the artifact must be met in implementing the proposed design features. Ultimately, I deduce the following propositions that can be used to assess the purposefulness and effectiveness of any IS instantiated based on the artifact (Walls et al., 1992):

(1) The artifact enables tailoring to users' individual characteristics.

(2) The artifact enables accompanying users along the behavior change process.

(3) The artifact ensures long-term changes in health-related behaviors.

6.2 Design Implications

The artifact developed in this study holds important implications for system providers who wish to design a persuasive health system using the presented guidelines. Providers in the context of information systems for health promotion may use the blueprint to guide the development of a persuasive health system and to support their decisions regarding the persuasive strategies to be offered to users. Being abstract in nature, the blueprint may be of use to system providers in various health-related contexts, for example, day-to-day activity, diet, sports, mental health, and disease self-management. The concrete tools that are part of the blueprint are useful in configuring digital health interventions and help bridge the gap between the generic problem class which the blueprint refers to and the specific problems and contexts in which individual systems operate.

In order to implement a persuasive health system developed based on the abstract blueprint I present in this paper a few prerequisites must be fulfilled and steps taken. First, there must be a solid technical basis to collect and present reliable data on which to build the persuasive components. Such technical prerequisites include, for example, sensor accuracy, correctness of data models, and continuity of data streams. Second, system providers must ensure data security and privacy protection. Privacy concerns are especially pronounced with older users (cf. Fox and Connolly, 2019) of persuasive health systems and need to be proactively addressed in order to prevent negative effects, like distrust or even discontinuance (Attig and Franke, 2020). Related to privacy concerns and trust-building, system providers should consider optionally allowing users to take some time to explore the new system before having to disclose intimate personal details as intended in DF1. Third, when designing features and configurations, the user-perspective must be included in an iterative process to avoid discrepancies between designers' intentions and users' interpretations of the affordances of a system (Rockmann and Gewald, 2018; Rieder et al., 2020a). Techniques, like over-the-shoulder interviews, are highly suitable to keep a user-centric focus during the entirety of the design process. Fourth, system providers must present a coherent offer. That is, value proposition, targeted user groups, purpose and context of the system as well as its specificity, technical properties, and the configuration of persuasion strategies must be inherently consistent and form a well-rounded solution. For example, a system to support users in improving sports performance must fit certain technical requirements to be able to capture specific performance parameters for sports, like heart-rate variability whereas other parameters (e.g., steps per day) may be negligible. Conversely, in the context of disease self-management or mental well-being, some social features that create transparence (e.g., challenges with friends) may be less suitable.

Furthermore, once implemented, persuasive health systems must be evaluated with regard to the effectiveness to fulfill the general (i.e., health behavior change, health improvements) and specific objectives (e.g., weight loss, increased well-being). Any evaluation should account for the following principles. First, the data upon which the evaluation is based must be fit to depict the effectiveness. On the general level, it is to say, that use statistics (e.g., checking frequencies, engagement in in-app social networks) are rarely appropriate to reflect the effectiveness of behavior change interventions. Rather, system providers should rely on behavior data, ideally complemented by cognitive categories to capture such non-behavioral effects, as learning, awareness, which represent valuable outcomes, too (Rieder et al., 2020a). With regard to the individual level, it is important not to compare individual performance with normative and standardized measures but to reflect on the meaning of the change for the individual user (cf. de Moya and Pallud, 2020). For example, a step-surplus of two thousand steps might be a good outcome for an inactive user but not for an ultramarathoner. Second, addressing the conceptualization of behavior change as a process with different stages, the selected baseline and observation periods are key and will determine the behavioral outcomes that can be made visible (cf. Jakicic et al., 2016); hence the great variance in the results of scientific studies on persuasive health systems' effectiveness.

7 Limitations and Further Research

The present study is subject to limitations which pave the way for future research efforts. First, with the artifact of this design science project being an abstract blueprint for the design of persuasive health systems, the proposed features were neither implemented nor assessed regarding their effectiveness to address the underlying challenges. Therefore, a follow-up study should be conducted in which persuasive systems for different health-contexts are developed based on this blueprint. Also, such a study should evaluate the effectiveness of these instantiations. Second, the presented artifact presumes users to possess basic knowledge about health behaviors and health consequences as well as sufficient technology-literacy and self-efficacy to adopt and use a persuasive health system. Future research may explore how potential users that do not satisfy these criteria (e.g., children, people with low health literacy, elderly people with low computer self-efficacy) may be reached and effectively targeted by persuasive health systems. Third, the presented artifact is limited in its scope to solve problems in the field of health promotion. However, guidelines for the design of persuasive health systems may also be useful in the healthcare domain, for example, for the management of serious diseases, treatment of psychiatric disorders, or recovery and rehabilitation. Thus, future research may propose a novel artifact for or extend the scope of the presented artifact to persuasive systems in healthcare.

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2. Lehrer, C., Eseryel, U.Y., Rieder, A., & Jung, R. (2021). Behavior Change through Wearables: The Interplay between Self-Leadership and IT-based Leadership. *Electronic Markets*. (doi: 10.1007/s12525-021-00474-3)
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2. Rieder, A., Vuckic, S., Schache, K., & Jung, R. (2020). Technostress from Persuasion: Wearable Users' Stressors, Strains, and Coping. *Proceedings of the 41st International Conference on Information Systems* (ICIS2020), Virtual Conference.
3. Rieder, A., Lehrer, C., & Jung, R. (2020). Affordances and Behavioral Outcomes of Wearable Activity Trackers. *Proceedings of the 28th European Conference on Information Systems* (ECIS2020), Virtual Conference.
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