DESIGN PRINCIPLES OF MOBILE INFORMATION SYSTEMS IN THE DIGITAL TRANSFORMATION OF THE WORKPLACE
–
UTILIZATION OF SMARTWATCH-BASED INFORMATION SYSTEMS IN THE CORPORATE CONTEXT

Dissertation

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List of Abbreviations

ACM	Association for Computing Machinery
AES	Advanced Encryption Standard
AIS	Association for Information Systems
AMCIS	Americas Conference on Information Systems
API	Application Programming Interface
App	Application
AR	Augmented Reality
BYOD	Bring Your Own Device
CAD	Computer-aided Design
CET	Cognitive Evaluation Theory
CHM	Corporate Health Management
CPS	Cyber-Physical System
CSS	Cascading Style Sheets
DOI	Diffusion Of Innovation
DP	Design Principle
DSR	Design Science Research
ECIS	European Conference on Information Systems
EXP	Experience Points
FBM	Fogg Behavior Model
FMR	Functional Meta Requirement
FR	Functional Requirement
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GSM	Global System for Mobile Communications

GST	Goal Setting Theory
HICSS	Hawaii International Conference on System Sciences
HRM	Human Resource management
HTML	Hypertext Markup Language
HTTP(S)	Hypertext Transfer Protocol (Secure)
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IHM	Ill-health Management
IMI	Intrinsic Motivation Inventory
IoT	Internet of Things
IP	Internet Protocol
IS	Information System
ISO	International Organization for Standardization
IT	Information Technology
JS	JavaScript
JSON	JavaScript Object Notation
LED	Light-emitting Diode
LTE	Long Term Evolution
MDA framework	Mechanics-Dynamics-Aesthetics framework
ML	Machine Learning
MRQ	Meta-Research Question
NFC	Near Field Communication
NFR	Non-functional Requirement
OS	Operation System
OSH	Occupational Safety and Health
PACMAD	People at the Centre of Mobile Application Development
PC	Personal Computer

PDA	Personal Digital Assistant
PHP	PHP: Hypertext Preprocessor
QA	Quality Assurance
QR Code	Quick Response Code
RC	Requirement Collaboration
REST	Representational State Transfer
RFID	Radio-frequency Identification
RL	Requirement Lone-working-protection
RNF	Requirement Non-Functional
RP	Requirement Patrol
RQ	Research Question
SDK	Software Development Kit
SDT	Self-Determination Theory
SIM	Subscriber Identification Module
SOA	Service-oriented Architecture
SQL	Structured Query Language
SSL	Secure Sockets Layer
SVM	Support Vector Machine
SW	SmartWatch
TAM	Technology Acceptance Model
TLS	Transport Layer Security
TOE-Framework	Technology-Organization-Environment-Framework
TOEI-Framework	Technology-Organization-Environment-Individual-Framework
TPB	Theory of Planned Behavior
UML	Unified Modeling Language
UMTS	Universal Mobile Telecommunication System
UTAUT	Unified Theory of Acceptance and Use of Technology

VR	Virtual Reality
WHO	World Health Organization
WHP	Workplace Health Promotion
WLAN	Wireless Local Area Network
XML	Extensible Markup Language

A Foundations

In the propaedeutic part of this cumulative thesis, the foundations that are relevant to the research contributions stated in part B are elaborated. As illustrated in Figure 1, this includes the motivation of the presented research described in section 1. Based on the introduction, the scope of the investigation is defined with the development of meta-research questions in section 2. In section 3, a detailed overview of the structure and course of action is provided. To supply contextual knowledge, the relevant literature, practice, theories, and methods used in this thesis are introduced in section 4. Finally, the overall research methodology illustrating the research framework and the integration of the individual study design is explained in section 5.

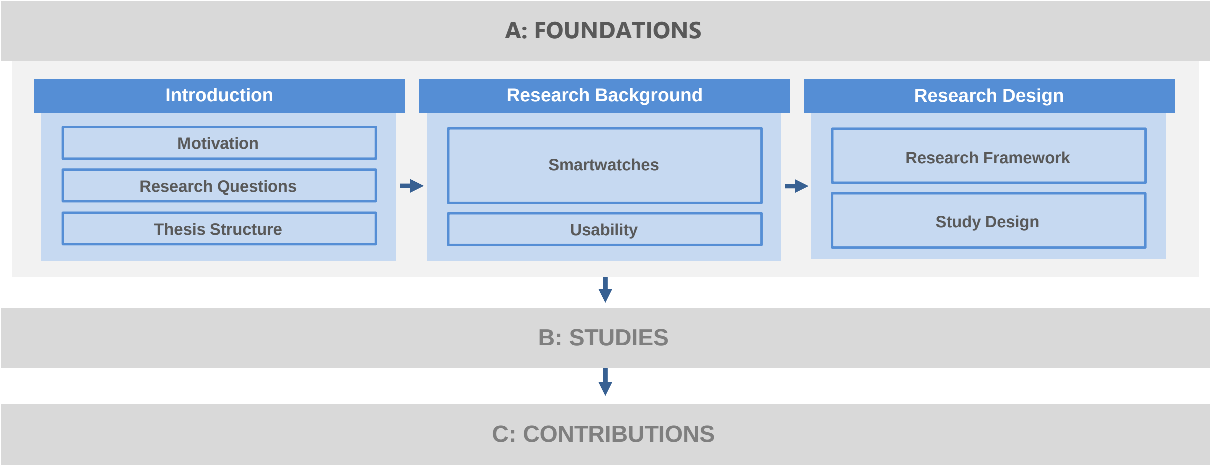


Figure 1. Structure of thesis’ part A presenting the foundations

1 Motivation

The impact of technological innovation is significant for everyone's everyday life, and society is quite accustomed to having ubiquitous digital access to the whole world, for example, in the form of a smartphone in their hands (Bartok / Maraczi 2019). Due to the ongoing technical development (Lasi et al. 2014) and miniaturization of hardware components (Narayanaswami et al. 2002) during the last decades, the class of wearable computers emerged and gained increasing practical relevance (Bartok / Maraczi 2019). In particular, smartwatches recently hit the consumer market and dominate the market of wearable computers (IDC 2020; TrendForce 2020). A reason for the immense success of smartwatches can be found in the public acceptance of these devices caused by the familiarity of ordinary wristwatches and the experience of well-being while wearing them (Wu et al. 2016; Jung et al. 2016). However, smartwatches are predominantly perceived as fashion products in the consumer market (Choi / Kim 2016), represent an additive for smartphones, and still, in 49.6 % of the smartwatch activations, the time is glanced and in 16.8 % notifications are read (Pizza et al. 2016).

Although the potential of smartwatches often is not used to its full capacity, they exhibit unique characteristics with the potential to be utilized within the corporate context (Hobert / Schumann 2017a; Schmidt et al. 2015). As all wearables, smartwatches are directly worn at the users' body and, in particular, are strapped at the users' wrist (Rawassizadeh et al. 2014). With this continuous combination of a body with an electronic device, which is not possible with other common devices, a smartwatch can obtain user and context related sensor information (Swan 2012). On the one hand, employees can access their health and well-being-related values to make their daily work more pleasant, and companies can offer special promotion programs supported with such digital systems to consolidate their workforce (Kim et al. 2019). On the other hand, context information can assist employees during their work, such as a recommender system (Adomavicius et al. 2005) or pervasive computing applications (Judd / Steenkiste 2003) appropriate to the employee's state and environment. Business challenges are becoming more complex, and due to the increasing degree of automation and standardization, the demands on employees raise (Schäfermeyer et al. 2012). Assistance systems in the form of smartwatches are always available and can reduce employees' cognitive load considering the context determined with various sensors and focus on relevant information and interaction opportunities (Sweller 2011).

Another aspect of smartwatches is realized through the possibility of direct vibrations at the employees' wrist without the need to continually pay attention to the device and wear it close to the body as in the case of a smartphone (Ogbanufe / Gerhart 2018). Visual and auditory signals cannot easily be recognized in loud or busy situations, are conspicuous, and disruptive in quiet or critical environments (Bresciani et al. 2008). Tactile signals can ubiquitously demand the employees' attention and are not visible in the environment.

Furthermore, the unique characteristics of smartwatches constitute the ability of incidental use and hands-free operability (Billinghurst / Starner 1999). The ongoing process of digitalization created the basis to provide digital support of employees with a digital exchange of information in many corporate domains like employees at office workplaces or a production line (Parviainen et al. 2017). Besides the digital support of stationary employees, mobile devices support employees executing work at different locations at least since the advent of the smartphone (Pitichat 2013). Nevertheless, as illustrated in Figure 2, a typical combination of work characteristics impedes the utilization of recently popular devices for support like desktop PCs, laptops, tablets, or smartphones: mobility of the employee coherent with manual work. Mobility implies that an employee has to work at different locations and thus does not have a permanent workstation. Manual work in this thesis is defined as physical work for that employees have to use their hands besides operating a digital device.

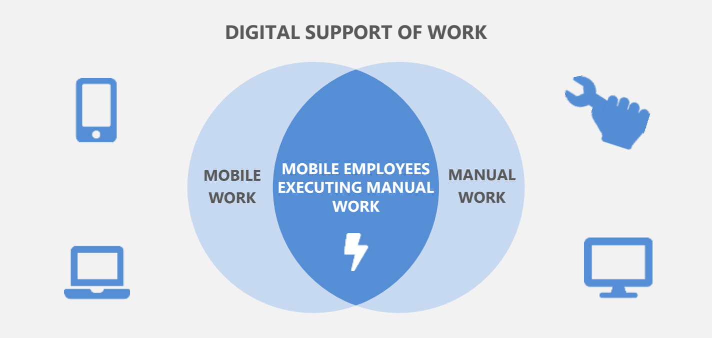


Figure 2. Digital support for different types of work

Mobile employees like insurance agents on an outdoor mission can easily rely on a mobile device as a laptop because they can operate the mobile device with their hands. Stationary employees executing manual work like in production line work are occupied with tools in their hands but can benefit from specially designed stationary systems such as monitors. Mobile employees executing manual work cannot carry such systems and have to interrupt work to operate mobile devices. Here, smartwatches offer high potential for digitalization and support of the described employees with the characteristics of permanent availability, easy observation, unobtrusiveness, easy handling, and portability on the body, allowing almost hands-free operation, especially for receiving information (Ziegler et al. 2015). Indeed, innovative technologies encounter resistance due to manifold reasons (Talke / Heidenreich 2014). For a successful long-term utilization of smartwatches in the corporate context, smartwatch applications have to provide appropriate usability enabling a high acceptance and efficiency (Chun et al. 2018). Furthermore, body-connected devices necessitate careful consideration of privacy (Jakobi et al. 2020).

Scientific research focused little on the advantages of utilizing smartwatches in the corporate context, and it remains a previously rarely considered research domain. Thus the support of employees during work becomes the focus of this thesis. The resulting objectives formulated in the research questions are argued in the following section.

2 Objectives and Research Questions

With the superordinate intention to contribute to the domain of design principles for mobile information systems in the digital transformation of the workplace, the particular objective of this thesis is to investigate the utilization of smartwatch-based information systems in the corporate context. Based on this objective, three research complexes are successively addressed to ensure a holistic investigation of the mentioned problem domain. For each research complex, meta-research questions (MRQ) are formulated constituting the orientation and purpose of this thesis and covering respective research gaps. The meta-research questions are refined and elaborated in part B of this cumulative thesis within the course of the individual research studies before they are finally summarized and answered in part C with the accentuation of the contributions.

As a prerequisite, the status of smartwatch-related research should be depicted to obtain an overview of recent efforts to integrate smartwatches into corporate processes and the daily work of employees. As the utilization of smartwatches in the corporate context is a strongly practice-oriented subject, this is complemented with a survey of the smartwatch-software market. In this way, it is possible to identify research gaps and so far unsatisfied demands building the foundation for the following objectives organized in research complexes.

RESEARCH COMPLEX I:
SMARTWATCH-BASED IS SUPPORTING MOBILE EMPLOYEES EXECUTING MANUAL WORK

MRQ 1: How to design smartwatch-based information systems to support mobile employees executing manual work?

- **MRQ 1.1:** How to design smartwatch-based information systems for typical corporate scenarios?
- **MRQ 1.2:** What enabling and inhibiting factors for the adoption of smartwatch-based information systems exist?
- **MRQ 1.3:** How to generalize and assemble the gathered knowledge?

The first research complex I addresses the support of mobile employees executing manual work with smartwatch-based information systems. This target area is selected because employees and companies can benefit from the full potential of the unique smartwatch device characteristics like an incidental exchange of information and hands-free operation. To elaborate on this central research complex, the MRQ 1 investigating how to design smartwatch-based IS to support mobile employees executing manual work is subdivided. First, in MRQ 1.1, typical corporate scenarios are selected, and for each, the design of a situated smartwatch-based information system is studied. MRQ 1.2 focuses on enabling and inhibiting factors for the adoption of smartwatch-based IS by companies constituting technical, organizational, environmental, and individual prerequisites. Finally, MRQ 1.3 aspires to a generalization of the individual use cases and recent findings. Therefore, Zenker / Hobert (2019, study 1) investigate the design and implementation of a collaborative smartwatch application supporting employees in industrial workflows within a production use case. Besides, Zenker et al. (2020b, study 2) cover a support use case while developing the *Smartwatch Applicability Framework* exploring the adoption of a smartwatch-based information system assisting support employees. Moreover, Zenker (2020, study 3) analyzes the utilization of a smartwatch-based system to support security service employees. Concluding, Zenker et al. (2020a, study 4) summarize the previous studies and evaluate a smartwatch-based system in a logistics use case to gather the obtained knowledge and to generalize the problem to a problem class as well as the solution to the level of design principles. This is documented in a nascent design theory.

RESEARCH COMPLEX II:
SMARTWATCH-BASED IS AT THE OFFICE WORKPLACE

MRQ 2: How to utilize smartwatch-based information systems at the office workplace?

Research complex II addresses smartwatch-based information systems at the office workplace to broaden the view on the utilization of smartwatches in the corporate context. Mobile scenarios are covered during the first research complex, and thus the second complex complements the study with stationary aspects. Since smartwatches are devices constructed for mobile use, the utilization in low mobile or stationary scenarios seems oppositional. Nevertheless, smartwatches also exhibit the characteristic of a wearable computer and are directly connected to the employee’s body (Rhodes 1997). With various sensors, they, on the one hand, can perceive employee-, environment and therefore context-related information (Rawassizadeh et al. 2015) and on the other hand, can demand the employees’ attention with proactive notifications which are accompanied by a vibration (Dvorak 2007; Bub et al. 2018). MRQ 1 consequently elaborates on the utilization of a smartwatch-based IS at the office workplace. Wesseloh et al. (2020b, study 5) thus examine health promotion at office workplaces with a gamified and smartwatch-based information system.

RESEARCH COMPLEX III:
USABILITY OF SMARTWATCH-BASED INFORMATION SYSTEMS

MRQ 3: How to analyze the usability of smartwatch applications?

Combined, research complex I and II composed of mobile and stationary corporate scenarios can already cover the design-oriented problem of this thesis. However, in particular with innovative devices and the limitation to small touchscreens, usability is a critical success factor in terms of efficiency and acceptance. Since the usability analysis is an essential element during the design and development of smartwatch applications and research has not provided applicable methods and tools assessing usability on smartwatches yet, research complex III comprise the usability of smartwatch-based information systems. As an auxiliary tool for the studies within the first and second research complex, MRQ 3 investigates the usability analysis of smartwatch applications. Zenker / Hobert (2020, study 6) address this research question with the design and implementation of a usability-framework for smartwatches.

Overall the thesis contributes to research and practice on the one hand with a design-oriented and constructive approach (research complex I and II) and on the other hand with an additive-building approach (research complex III) as summarized in Table 1.

CONTRIBUTIONS FOR RESEARCH	CONTRIBUTIONS FOR PRACTICE
• **Systematization** of the state-of-the-art • **Enabling and inhibiting influence factors** of the smartwatch adoption in companies • **Design principles** and a **nascent design theory** for smartwatch-based IS to support mobile employees executing manual work	• Possible **use cases** for smartwatches in companies • Assistance in **decision-making** for the introduction of smartwatch-based IS in the corporate context • **Situated implementations** of a smartwatch-based IS for typical use cases • **Design recommendations** for smartwatch-based IS • **Implementation of a smartwatch-based IS** for the support of mobile employees executing manual work • A **usability-framework for smartwatches** to automatically access usability of existing applications providing suggestions for usability improvement • A **process model** for the introduction of smartwatch-based IS in the corporate context

Table 1. Contributions of the thesis for research and practice

3 Structure of the Thesis

This section provides an overview of the thesis' structure. It is composed of three parts: (A) the foundations, (B) the studies, and (C) the contributions. Figure 3 illustrates the overall procedure.

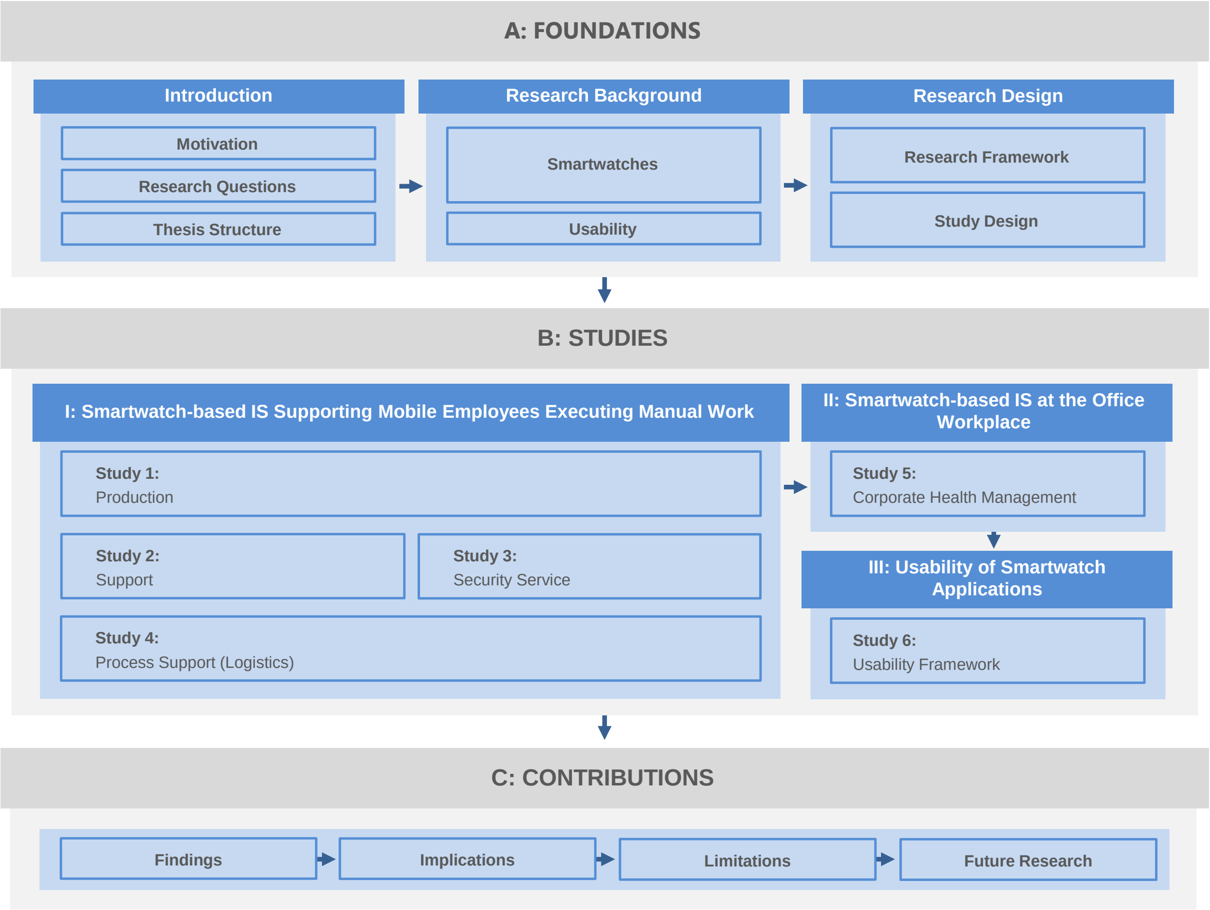


Figure 3. Structure of the thesis

Part A outlines the foundations, which initially provide an introduction including a motivation (A.1), the objectives of the thesis formulated in the form of research questions (A.2), and details about the thesis structure (A.3). Second, the research background (A.4) is presented, including the introduction of the terms smartwatch and usability during smartwatch development that are relevant in this thesis. Besides, related research is mentioned for each topic. Finally, the overall research design (A.5) of the thesis is described methodically by illustrating the applied research procedure.

Part B shows the individual research contributions arranged in research complexes required to develop a well-rounded impression of the utilization of smartwatch-based IS in the corporate context. Table 2 provides an overview of the individual research contributions, the respective citation within this thesis, the outlet, the publication status, and a summary of the main contributions.

	Citation	Main Contribution
Complex I	**Study 1: Design and Implementation of a collaborative Smartwatch Application Supporting Employees in Industrial Workflows (Zenker / Hobert 2019, study 1)**	
	ECIS 2019 (published)	Design, development, and evaluation of the *smartActivity* artifact within a production scenario.
	Study 2: The Smartwatch Applicability Framework: Adoption of a Smartwatch-based Information System Assisting Support Employees (Zenker et al. 2020b, study 2)	
	ECIS 2020 (published)	Design, development, and evaluation of the *supportWatch* artifact within a support scenario. Investigation of enabling and inhibiting factors of smartwatch adoption in companies. Development of the *Smartwatch Applicability Framework*.
	Study 3: Utilizing a Smartwatch-based System to Support Security Service Employees (Zenker 2020, study 3)	
	AMCIS 2020 (published)	Design, development, and evaluation of the *smartSecurity* artifact within a security service scenario.
	Study 4: Designing Smartwatch-based Information Systems to Support Mobile Employees Executing Manual Work (Zenker et al. 2020a, study 4)	
	under review	Design, development, and evaluation of the *watchIT* meta-artifact, as well as the proposal of a nascent design theory for smartwatch-based IS supporting mobile employees executing manual work.
Complex II	**Study 5: Promoting Health at Office Workplaces with a Gamified and Smartwatch-based Information System (Wesseloh et al. 2020b, study 5)**	
	under review	Design and development of the gamified and smartwatch-based IS *healthWatch* for corporate health management.
Complex III	**Study 6: Design and Implementation of a Usability-Framework for Smartwatches (Zenker / Hobert 2020, study 6)**	
	HICSS 2020 (published, best paper nominee)	Design, development, and evaluation of the *usabilityWatch* artifact to analyze the usability of smartwatch applications.

Table 2. Research papers contributing to the thesis

The remainder of this section introduces the research complexes and discusses how each paper is situated within the respective complex. Complex I addresses the support of mobile employees executing manual work with a smartwatch-based IS. During five design science research cycles, the different use cases production (Zenker / Hobert 2019, study 1), support (Zenker et al. 2020b, study 2), security service (Zenker 2020, study 3), and logistics (Zenker et al. 2020a, study 4) are examined. Furthermore, a generalization step for this problem domain is realized, and a design theory is proposed (Zenker et al. 2020a, study 4). Research complex II investigates smartwatch-based IS at an office workplace to complement the view of a smartwatch-based IS with a stationary aspect. Therefore, a use case of corporate health management is analyzed, and a gamified and smartwatch-based IS promoting health at office workplaces is designed, implemented, and evaluated (Wesseloh et al. 2020b, study 5). Finally, in research complex III, the usability of smartwatch applications as an essential success factor of smartwatch-based IS is covered. For that, a usability framework is designed, implemented, and evaluated during a design science research inspired approach (Zenker / Hobert 2020, study 6).

Part C summarizes the results of the research contributions presented in part B of this thesis, as shown in Figure 3. First, the findings (C.1) based on the various artifacts developed during the design science process are outlined at the level of each research complex regarding the research questions developed in A.2. After the research questions have been addressed by the presented results, the implications for research and practice are discussed (C.2). Furthermore, the limitations of this thesis (C.3) are elaborated, and finally, opportunities for future research (C.4) based on the presented results are argued.

4 Research Background

This section provides an introduction to the research background, illustrates the context, and integrates the studies presented in part B based on extant literature. First, the basic terms smartwatch and usability are explained and defined. Second, the state of research and practice is surveyed during a structured literature review to identify connecting factors and research gaps.

4.1 Smartwatch

The wristwatch is one of the oldest wearable technologies allowing to access the time and related information at a glance and become common for women in the late 1800s, followed by men in the early 1900s (Martin 2002). The design of the wristwatch originates in the adoption of pocket watches by the military due to the necessity of time-coordinated maneuvers and the advance for soldiers to keep their hands free when checking the time (Martin 2002). Digital watches succeeded as a technological evolution (Piguet 2002), followed by HP's *calculator watch* in 1978 and watches with various features like radio and television (Beringer 1984). While moving towards smartwatches, there have been computer-watches such as the Swatch/HP's *Webwatch* (Smith 2007), the Microsoft *SPOT* (Smart Personal Objects Technology) that was able to display selected web contents (Krumm et al. 2003), and wrist-PDAs. In the last decade, the history of the exemption from manual operation and miniaturization of tools recurs with the contemporary world's computational form factor of choice: the smartphone. It supports various activities and enables versatile media consumption. The smartwatch adopts functionality from the mobile phone (smartphone) in a well-designed and consumer-accessible form, although the technology is not a radical advance. Smartwatches are built around notifications, a quick gain of information at a glance (Pizza et al. 2016). Besides, various wrist-worn non-watch wearables targeting health, fitness, and the quantification of personal actions emerged due to the ability to track health parameters at the users' wrist (Swan 2012).

As a product of new demands on mobility and technological progress, including continuing miniaturization of computer components (Peercy 2000), beyond smartwatches, the category of wearable computer emerged in the last decades (Boronowsky et al. 2008). These devices are directly worn on the users' body and hence provide unique characteristics as they are permanently active, designed for mobile use, and provide non-manual operation (Rhodes 1997; Starner 2001; Dvorak 2007; Witt 2007). Wearable computers are no longer understood exclusively in the context of hardware components, and therefore the functionalities provided by the software for the respective user are also considered (Dvorak 2007; Witt 2007). In this way, wearable information systems can assist the user in a broad range of everyday activities or work processes and assist the user through (proactive) support (Dvorak 2007). Besides smartwatches, the class of wearable computers is composed of smart glasses and smart clothes as the most famous and established representatives. Smart glasses like *Google Glass* (Google 2020b) or *Epson Moverio* (SEIKO Epson CORPORATION 2020) are head-mounted displays and hence are worn permanently on the head of the user as ordinary glasses (Witt 2007). With the integrated display, digital information can be integrated into the user's field of vision, and an augmentation of the physical environment can be provided (Azuma et al. 2001). Smart cloths subsume textiles or similar materials with integrated electronic systems (McCann / Bryson 2009). This combination enables the wearer of such a garment to access the functionalities provided by the electronic system as the initialization of interaction capabilities (e.g., operation of machines), or the perception of body values of the user with the integrated sensors (Cho et al. 2009).

Smartwatches currently dominate the wearable computer market due to their positively perceived attitude and values (Hsiao / Chen 2018; Rawassizadeh et al. 2014). They exhibit a high acceptance in the social environment, and the users feel comfortable wearing the device due to the high similarity to ordinary watches (Choi / Kim 2016). Smartwatches represent a special occurrence of mobile computers and are shaped in the form of a digital wristwatch (Cecchinato et al. 2018). They are assembled of standard computer hardware such as a processor, memory, and battery. Also, they are equipped with various sensors to perceive the environment and wireless interfaces for communication as wireless, Near Field Communication (NFC), Global Positioning System (GPS), Bluetooth, or GSM, as well as speaker and microphones. Besides, they can be operated with a touchscreen, voice control, motion gesture control, or several hardware buttons as well as a digital lunette (Bieber et al. 2012; Chuah et al. 2016; Pascoe / Thomson 2007). Smartwatches delimit from other mobile devices with a similar shape like fitness trackers since they run a hardware-independent operating system, which can be extended by installable applications (Rawassizadeh et al. 2014). Besides, the functionality of some devices originates from the interconnection with a smartphone, which then is merely smartphone accessories (McGrath et al. 2013). In this thesis, the term smartwatch relies on the following definition composing all relevant aspects mentioned above:

> A **smartwatch** is a standalone, miniaturized computer in the form of a wristwatch equipped with a touchscreen and hardware buttons for operation, various sensors to gather information about the real-world context, and wireless interfaces for communication. It runs a hardware-independent operation system that functionality can be extended by custom applications.

Figure 4 shows the smartwatches the thesis' studies rely on, as an example. From left to right, the smartwatch models (1) *Huawei Watch 2*, (2) *Fossil FTW4018*, (3) *Skagen SKT5100*, and (4) *Diesel Full Guard 2.5 (DZT2008)* are used. The particular specifications can be found in Table 34 of appendix 1. This selection of smartwatches represents a cross-section of the diverse market of smartwatches based on *Wear OS* (until 03/2018 called *Android Wear*) by *Google* and exhibit different form factors and forms of hardware buttons (Google and Open Handset Alliance 2020). *Wear OS* allows, as is known from smartphones and derivate from the smartphone operating system *Android*, third-party applications and thereby extend the device's functionality. Besides, *Apple* offers the *Apple Watch* operated with *watchOS* within its particular smartwatch ecosystem (Apple Inc. 2020b). Apart from the two market leaders, there is a recent trend of heterogenization of the smartwatch operating system market, and each manufacturer develops a separate and proprietary system. In this research context, *Wear OS* has been selected to be utilized in the studies since the software is freely accessible, and there is a broad range of devices of different manufacturers.

Figure 4. The smartwatch devices used in this thesis

Smartwatches are worn directly on the users' body, are always available, and can therefore demand a users' attention proactively with haptic feedback in the form of vibrations to initiate interactions (e.g., reaction to a notification), independently of a specific location or time (Boronowsky et al. 2008; Jiang et al. 2015; Rhodes 1997). Nevertheless, smartwatches are usually limited to simple input and output options during the operation through a user due to the small form factor (Malu / Findlater 2015). Nevertheless, a smartwatch can permanently gather information about the environment or the person wearing it in the background using various sensors listed in Table 3 (Reeder / David 2016). This, on the one hand, provides a broad range of applications concerning context-sensitivity and the tracking of the users' body values (Rawassizadeh et al. 2015), but on the other hand, the potential to record, transfer, and process person-related health and environmental data add another aspect of privacy concerns and a feeling of surveillance (Udoh / Alkharashi 2016; Ernst / Ernst 2016).

Sensor	Value
Accelerometer	Tri-axial acceleration of the wrist
Gyroscope	Tri-axial rotation of the wrist
Microphone	Sound intensity of the surrounding
Optical sensors	The intensity of light angle reflection
Contact sensors	Temperature
Barometer	Air pressure
Ambient light sensors	The intensity of the surrounding light

Table 3. Smartwatch sensors

For example, Figure 5 shows the optical sensors at the back of the *Fossil* smartwatch, which continuously measure the users' heart rate (Phan et al. 2015). Despite the large spectrum of smartwatch sensors, some challenges limit the real-world application (Giordano / Puccinelli 2015). (1) The small capacity of batteries limits the use of resource-consuming sensors, e.g., GPS, that can lead to a sparsity of the data (Bisdikian et al. 2009). (2) The small scale of the sensor hardware, including GPS, Bluetooth, and W-LAN, may provoke less accuracy (Rawassizadeh et al. 2014). Moreover, (3) automatically recorded contextual data is highly sensitive, and privacy must be considered (Miluzzo et al. 2012; Rawassizadeh / Tjoa 2010).

Figure 5. The contact sensor for pulse measurement of a smartwatch

4.2 Usability during smartwatch development processes

The user-friendliness or usability of an application can be considered as a quality feature of a product and is defined as intuitive access to the operation of a product to accomplish a specific task (Nielsen 1994). Usability is thus understood as a pragmatic quality of software in terms of the achievement of objectives. Usability is defined according to ISO 9241-11 (International Organization for Standardization 2008) as the product of

1. **effectiveness** in the sense of usability for the fulfillment of tasks,
2. **efficiency** as a measure of the time and effort required to fulfill tasks, and
3. **satisfaction** as a measure for the positive attitude towards the use of the product in a particular context.

It has to be distinguished from user experience, which is the users' perception of a system considering the expected utility (Hassenzahl / Tractinsky 2006). According to ISO 9241-210 (International Organization for Standardization 2019), the user experience is defined as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service." Thus this term extends the perspective of a persons' attitude before and after use, whereas usability is a concept considered during the use of a system.

Besides, Nielsen (1994) considers the following criteria to play an essential role in usability:

1. **learnability** - how easy can a user learn the operation of an application,
2. **memorability** - how good can a user operate an application after a certain amount of time without use, and
3. **error frequency** - how many errors does a user provoke, how serious are these errors, and how easily the user can find a solution to resolve the problem.

The mentioned usability attributes can be assigned to the *People at the Centre of Mobile Application Development* (PACMAD) model illustrated in Figure 6 (Harrison et al. 2013).

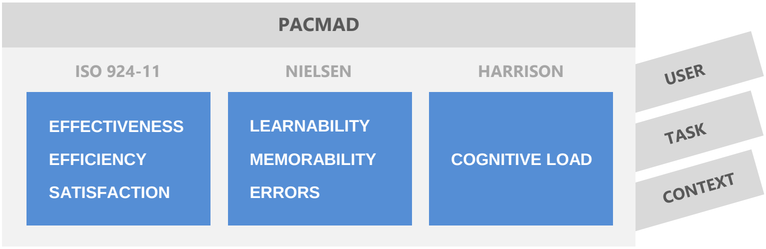


Figure 6. The PACMAD usability model

The PACMAD model focuses on the usability of a mobile application and identifies the user, the task, and the context as the primary influencing factors for usability. The context got a particular role, as the applications are used in different contexts under various influencing conditions. This factor gets even more critical regarding smartwatches since the devices, concerning their form factor, are used in highly dynamic contexts. Due to this high mobility, including simultaneous or interfering activities and environmental influences, a user's full cognitive attention cannot be presumed as in traditional usability investigations of desktop applications. For this reason, PACMAD uses the cognitive load, which is necessitated by an application as a core usability attribute (Harrison et al. 2013).

The importance of usability for a system, for instance, can be derived from the Technology Acceptance Model (TAM) according to Davis et al. (1989), which describes the influencing factors of the usage of an information system. As illustrated in Figure 7, the TAM explains the usage behavior with the determinants of the **perceived usefulness** and the **perceived ease of use**.

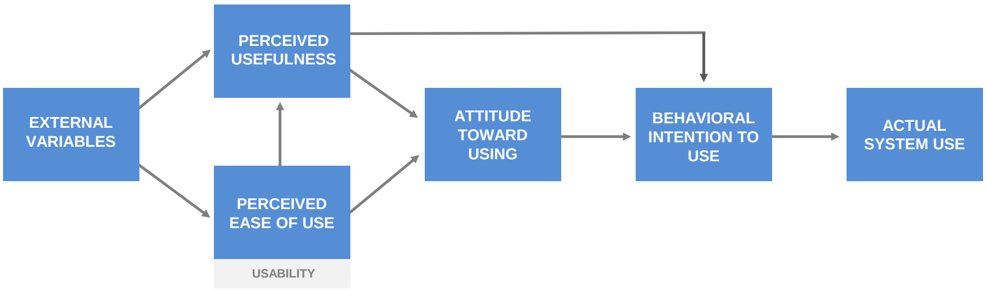


Figure 7. The Technology Acceptance Model

According to the definition of usability, it can be assigned to the lower determinant, which significantly influences the perceived usefulness and thus indirectly and directly affects the attitude toward using a system (Venkatesh / Davis 1996). Besides, Nielsen (1994) considers usability as a determinate for practical acceptance and, consequently, for the systems' acceptance.

During a usability evaluation, unfavorable factors provoking a negative chain of effects illustrated in Figure 8 should be identified, and the usability of a system should be increased (Watbled et al. 2018). A usability problem can be defined as a problem that a user encounters when using the system to complete a task within an application scenario (Alshamari / Mayhew 2009). A usage problem is attributed to a usability defect arising from a violation of a usability principle and can negatively affect the user (Marcilly et al. 2015).

Figure 8. Negative chain of effects related to a violation of a usability principle

For the early detection of problems and thus avoiding and limiting the negative consequences, usability evaluation methods are used. The methods can be classified into qualitative methods producing data, which has to be interpreted (testing, observing, and questioning), and quantitative methods, which are based on defined metrics having numerical and objective data as a result (simulation and analytical modeling) (Ivory / Hearst 2001). For qualitative methods, moderated method types with little automation are common, such as observation and recording, interviews, think-aloud protocols, or heuristic methods. For quantitative methods in practice, unmoderated method types are frequently used, such as online questionnaires based on the usability scale system (Tullis / Albert 2013), the automated metric recording of an object of investigation, or a task model (Nielsen 1994).

The methods are used in various test environments, which is one influencing factor in the four-factor framework of contextual fidelity that describes the quality of the results of a usability evaluation (Sauer et al. 2019). Accordingly, the test environment has to resemble the real operational environment to avoid a negative impact on quality. The laboratory test is one of the most frequently used test environments (Kolbe / Ruch 2014) since it takes place in a controlled and fully definable context, almost free of accidental environmental influences. This allows collecting data through various instruments during a moderated evaluation, which is highly specified and consequently precisely reproducible. Due to the versatile use cases of a smartwatch, the simulation of the particular environment in a laboratory test is a considerable challenge (Zhang / Adipat 2005). The research on automated usability measurement of smartwatches is still in its infancy. On the one hand, recent methods split into the **static analysis**, evaluating the source code, and especially the design files during the development (Louridas 2006). On the other hand, the **dynamic analysis** considers user interactions and is for the scope of this thesis involving domain experts in studies more convenient. For the dynamic usability analysis, there are several approaches from other application domains. Lettner / Holzmann (2012) developed an automated and unsupervised system for usability evaluation by user interaction logging. Usability smells as an indication of a usability defect can be exploited (Almeida et al. 2015). Several studies investigated the analysis of data logged during user interaction like Grigera et al. (2017) who used usability smells to automatically generate a usability report for websites, Harms / Grabowski (2014) who automatically detect usage-based usability smells in web applications, Harms (2006) elaborated on automated field usability evaluation while using generated task trees, and an automated usability evaluation of virtual reality applications (Harms 2019).

Usability in this thesis is an auxiliary construct utilized during the design and development of smartwatch applications. Nevertheless, usability is a crucial factor for the acceptance of smartwatch-based IS and thus has to be considered during software development. Although there are currently no specific methods to assess the usability of smartwatch applications, these foundations can constitute a starting point for an adaption and extension of the knowledge about mobile usability.

4.3 Related Research and Practice

In this section, the extant literature is analyzed to determine the current state of research and practice in the domain of the utilization of smartwatches in the corporate context as an empirical prerequisite for the studies in part B. To apply an appropriate procedure, a structured literature review according to vom Brocke et al. (2015), vom Brocke et al. (2009), Fettke (2006), and Webster / Watson (2002) is conducted. With this methodology, the state-of-the-art and related research should be surveyed during a sequential review process subdivided into five steps illustrated in Figure 9.

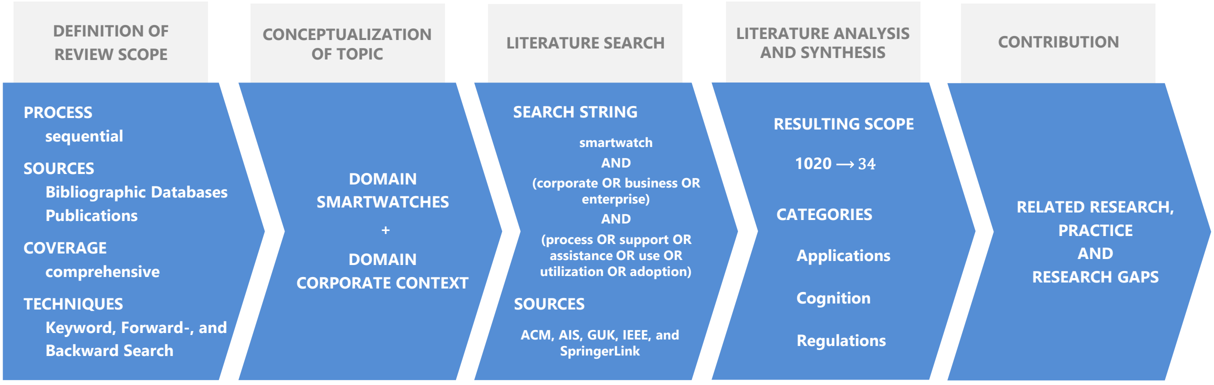


Figure 9. Steps of the literature review

The first step of the structured literature review comprises the definition of the review focus. Based on the framework of vom Brocke et al. (2015), it should (1) rely on a sequential search process since the goal is to assess the state of research and practice at present. (2) The literature review draws on publication outlets and bibliographic databases as the focus is to identify research outcomes and applications representing central issues of the domain of smartwatch utilization in the corporate context. The following databases are common within the information systems research stream, comprise the smartwatch-relevant aspects, including relevant literature from journals, conferences, and scientific thesis, and are thus selected:

- ACM Digital Library
- AIS Electronic Library
- Göttingen University Catalogue (GUK)
- IEEE Xplore Digital Library
- SpringerLink

(3) To gain a holistic view, the literature search should be comprehensive. Since an overarching search for smartwatch-related literature is unfeasible, the review focuses on scientific articles about smartwatches within the corporate context. Finally, (4) the literature review relies on a keyword search with a subsequent forward and backward search (Webster / Watson 2002).

To structure the literature search results thematically, a systematization of the topic is conducted in the second phase. As mentioned in the previous sections, the utilization of smartwatches in the application domain of the corporate context is targeted.

The third step of the literature review includes the literature search to collect a reference set of literature, in which the relevant articles are identified. Although the targeted research domain has developed considerably in recent years due to technical progress, no limitation of the considered period was applied not to exclude older contributions. Nevertheless, while examining the publications' relevance, it was ensured that the articles are up-to-date according to the state-of-the-art or use appropriate prerequisites. To complement the contributions, a forward and backward search was performed. As shown in Table 4, in total, the search results in 1020 articles found in the scientific databases. The articles' relevance was checked by first analyzing the title, second the abstract, and finally, the entire scope. Contributions are excluded due to the following reasons noted in the search protocol (vom Brocke et al. 2015):

- The publication is not a full scientific contribution (e.g., editorials and comments). ⟶ **119**
- The publication is an own contribution and included in this thesis. ⟶ **4**
- The publication targets the consumer and not the corporate context. ⟶ **43**
- The publication's focus is not smartwatch specific (e.g., wearable computer). ⟶ **668**
- The publication focuses on generic hardware and software-engineering aspects. ⟶ **55**
- The publication targets different application domains (e.g., medical applications). ⟶ **98**

In this way, and after removing the duplicates, 31 articles were classified as relevant, representing 3 % of the total extent. Furthermore, three articles could be added during the forward-backward search resulting in a final set of 36 relevant articles.

	Articles	
Source	**considered**	**relevant**
ACM Digital Library	218	8
AIS Electronic Library	133	11
Göttingen University Catalogue (GUK)	0	0
IEEE Xplore Digital Library	12	5
SpringerLink	657	7
total	**1020**	**31**
with forward- and backward search		**34**

Table 4. Considered databases and analyzed articles

The fourth step of the literature review comprises the analysis of the identified publications. The research on smartwatches in the corporate context is still in its infancy, which is clarified by the low amount of research articles and the time of the publications ranging from 2014 until 2020. The results are categorized into three groups: (1) applications including articles regarding the support of employees in corporate workflows and health and well-being, (2) cognition including contributions according to gesture control and the utilization of sensor data, and (3) regulations including articles about security and privacy in the corporate context. The publications ordered by their occurrence shown in Table 5 are introduced and discussed below.

SMARTWATCHES IN THE CORPORATE CONTEXT	**Applications**	**Support of Employees in Workflows**	Aehnelt / Urban 2014, Aehnelt / Urban 2015, Hobert / Schumann 2017a, Schönig et al. 2018, Hobert / Schumann 2018, Knote 2019, Mueller et al. 2020
		Health and Well-being	Giddens et al. 2017, Baig et al. 2019, El-Gayar et al. 2019, Meyer et al. 2019, Siirtola 2019, Xiao-Liang Shen et al. 2020
	Cognition	**Gestures**	Guo / Paek 2016, Mondol / Stankovic 2020
		Sensors	Bojanovsky et al. 2017, Misbhauddin 2020, Akpinar et al. 2020, Lee et al. 2020
	Regulations	**Security**	Migicovsky et al. 2014, Bodin et al. 2015, Ferrari et al. 2015, Maiti et al. 2016, Siboni et al. 2018a, Siboni et al. 2018b, Guerar et al. 2019, Shen et al. 2020
		Privacy	Ernst / Ernst 2016, Kupfer et al. 2018, Mainali / Shepherd 2019, Paul et al. 2020

Table 5. Results of the literature review

The first group of publications addresses **applications** of smartwatches in the corporate context. On the one hand, there are several approaches to support employees in workflows. Aehnelt / Urban (2014) analyze the systematic information transfer between assistance systems and workers and develop a theoretical model about the assistance on the shop floor following educational objectives. They implement the approach on a smartwatch for application in industrial assembly environments. Based on that, Aehnelt / Urban (2015) provide a conceptual approach towards using cognitive architectures to provide information assistance and allow complex decision making on the shop floor and extend their smartwatch application with it. Knote (2019) investigates smart assistance systems for physical and manual tasks to increase job satisfaction and performance. He elaborates on requirements for systems that provide employees additional information and guidance during their work. Similar to that, Schönig et al. (2018) analyze workflow support in wearable production information systems. They describe an internet of things aware business process management system and exploit smartwatches to notify employees whenever human interaction is required. Hobert / Schumann (2017a) investigate the adoption of wearable computers in enterprises and elaborate on influencing factors and challenges in the industrial sector. Hobert / Schumann (2018) extend this effort and provide ten lessons learned about enterprise wearable computer systems, including smartwatches. This describes practical advice that should be considered during the conception of wearable systems in the industry. Mueller et al. (2020) investigate smart devices for a dynamic cognitive assistance system for repair processes in production. They evaluate and compare different types and configurations of smart devices. Predominantly, assistance systems that provide ubiquitous information and guidance have been researched. In particular, smartwatch-based IS for collaborative process support of mobile employees executing manual work remain a research gap.

On the other hand, health and well-being applications for smartwatches are the focus of research. For this literature review, medical aspects of smartwatches are excluded due to their unconfirmed reliability and accuracy (van Helmond et al. 2019), as well as direct relevance to work processes and employers overshadowed by crucial privacy aspects (Meingast et al. 2006). Giddens et al. (2017) analyze the role of wristbands in corporate wellness programs. Their research shows that the well-being of employees can be enriched by using such devices. Baig et al. (2019) elaborate on current challenges and barriers to adopting wearable sensor applications in health and well-being. Besides, El-Gayar et al. (2019) also analyze challenges based on insights from Twitter. Meyer et al. (2019) review the role of mobile emotion measurement and recognition, which can be done with a smartwatch for a better and more personalized digital advisory. Siirtola (2019) investigates continuous stress detection using the sensors of commercial smartwatches. She surveys what sensors recent smartwatches currently include and how accurately stress can be detected user-independently using different sensor combinations. Xiao-Liang Shen et al. (2020) investigate the intermittent continuance of smart health devices and employs the zone-of-tolerance theory to explore the mechanisms through which intermittent continuance is evoked. Although there is a lot of conceptual and socio-technical research according to health and well-being applications, design knowledge of smartwatch-based IS in this domain is missing and represents a research gap.

The second group of publications addresses the **cognition** features of smartwatches utilized in the corporate context. On the one hand, research targets the operation of smartwatches with motion gestures. For that, Guo / Paek (2016) explore tilt for no-touch, wrist-only interactions on smartwatches. Since smartwatches have to be operated by hand on the touchscreen for manipulation tasks, they seek more “hands-free” smartwatch interactions. Besides, Mondol / Stankovic (2020) investigate handwashing detection using wrist wearable inertial sensors. This can help employees to improve hygiene, for example, in the food business. On the other hand, sensors are exploited to gather contextual information or to extend input capabilities. Bojanovsky et al. (2017) evaluate fall and seizure detection with smartphone and smartwatch devices. They observe up to 98.5 % accuracy and thus high reliability of the analysis of sensor data. Misbhauddin (2020) presents a smartwatch-based system for driver drowsiness detection. They demonstrated the utility of wearable assistance systems providing real-time feedback with a precision of 97 %. Akpinar et al. (2020) systematically reviewed the effect of context on small screens regarding the users’ performance. They identified physical, temporal, social, task, and technical factors for context analysis that significantly impact the users’ performance. Lee et al. (2020) present an approach to solving the complication of interaction with content on small-scale touchscreens with a force-assisted miniature keyboard on smart wearables. Besides the two dimensional surface of the display, they exploit the force of touches as a third dimension to add more options for improved and faster interaction. The gesture-based operation and the inclusion of various sensor data provide massive potential for seamless integration of smartwatches in an employees' daily work, creating added value. Context information can be evaluated to customize the information displayed on the small screen, increase workflows' efficiency, and reduce the cognitive load through smart assistance (Sweller 2011).

Regulations and general conditions classify the third and last group of publications. First, it covers security-oriented research on smartwatches. Migicovsky et al. (2014) accentuate that wearable technology like smartwatches enables exciting new applications in the corporate context, although new security and privacy concerns arise. As proof of concept, they analyze the outsmarting of proctors with smartwatches during a case study on wearable computing security. Bodin et al. (2015) investigate security challenges and data implications using smartwatch devices in the enterprise. They attempt to bring different views on how data security and usability are essential for enterprise IT to adopt this type of Internet of Things (IoT) device in the corporate context. Siboni et al. (2018a) and Siboni et al. (2018b) emphasize that the use of personal IoT devices, such as smartwatches, in a bring your own device (BYOD) program offers new potentials for attack scenarios and pose a mitigation mechanism for enterprise BYOD environments. They demonstrate how data from enterprise networks can leak using a compromised smartwatch device. Maiti et al. (2016) investigate the downside of state-of-the-art smartwatch sensors by exploiting motion sensors recognizing keystrokes on an external keyboard and infer the typed text. They develop and evaluate a novel context-aware protection framework that can be used to disable access to motion sensors automatically. To increase device security and only allow access to authorized employees, Shen et al. (2020) authenticate users in the mobile environment through waving gesture analysis. Guerar et al. (2019) introduce a pin-based authentication on smartwatches using two intuitive gestures providing high usability and resilience to common attacks. Ferrari et al. (2015) develop a gesture-based soft authentication method. Combining gesture analysis and Bluetooth, they allow employees to transfer privileges to colleagues by a handshake. Due to the high number of contributions, the security of smartwatch-based IS is a critical success factor but remains a challenge since many socio-technical aspects have to be considered.

Second, the privacy of smartwatch-based information systems is a focus of the research stream. Ernst / Ernst (2016) investigate the influence of privacy risk on smartwatch usage. They postulate that perceived privacy risk has a direct negative influence on the behavioral intention to use smartwatches since smartwatches can collect a broad range of physical activity data during usage. According to their work, smartwatch-based IS need to address people's potential negative perceptions of the devices in terms of their privacy. Paul et al. (2020) identify personal data collection as a significant barrier to the adoption of smartwatches. They thus examine privacy concerns regarding wearable IoT devices and focus on how it is influenced by the General Data Protection Regulation (GDPR). Kupfer et al. (2018)

investigate the ambiguous boundary between professional and private use of information systems. In particular, with smartwatch BYOD programs, these blurring boundaries can cause side effects that have to be considered. Mainali / Shepherd (2019) investigate how to utilize the motion sensors while respecting privacy in the use case of privacy-enhancing fall detection from remote sensor data using multi-party computation. Besides the security, employees' privacy seems to be a critical success factor for adopting smartwatch-based IS in companies. These findings motivate an early consideration of privacy aspects during a system design and development process and showcase several approaches.

So far, the literature review covered scientific publications. Since the utilization of smartwatches in the corporate context is a highly practice-driven domain, the review is complemented with a **market survey**. In the practical domain, some companies also developed approaches in the form of several smartwatch-based products. *MeisterTask* (MeisterLabs GmbH 2020) is a task management software that enables individuals and teams to organize, assign, and track their tasks digitally. It is made for desktop and mobile environments and provides smartwatch applications that display and notify tasks. T*askWatch* (Hipaax LLC 2020) is a system that transforms enterprise data into actionable and measurable tasks using wearable cloud infrastructure. Customized smartwatch applications can be built to display information on the enterprise systems on a smartwatch. *aucobo* (aucobo GmbH 2020) provides a smartwatch-based human-machine interface linking machines at a shop floor with smartwatches. Hence, the information flow from machines to the operators within production can be supported. *WORKERBASE* (WORKERBASE GmbH 2020) is a real-time work coordination tool for front-line workers. Besides stationary and mobile software components, they offer special smartwatch devices made for industrial scenarios, including a rugged design and the availability of a barcode scanner. However, the available products have a limited range of functionality, are not primarily centered around the unique smartwatch characteristics, are made for specific scenarios, utilize proprietary hardware, do not provide any scientific background, or are not eligible for scientific studies, since the source code cannot be accessed. In particular, these products do not enable companies to develop smartwatch-based IS on their own and for their specific needs. There is predominant confinement to industrial use cases neglecting the full potential of smartwatches, and socio-technical surrounding conditions are not considered. In total, the adoption of smartwatch-based IS by companies is in its infancy.

The results of the systematic literature review indicate that in large parts of the research area regarding the utilization of smartwatches in the corporate context, research gaps still exist. Although there are already first approaches and also products for a limited scope of application, general conclusions about the design of smartwatch based IS have not yet been formulated. Nevertheless, the publications offer reference points as related research, and the studies conducted within this cumulative thesis can thus benefit from the various recent findings. Based on the lack of design knowledge and design principles about smartwatch-based IS, research complex I addresses the digital support of mobile employees executing manual work with smartwatches. This research considers aspects of the group of workflow targeted applications, cognition, and regulations. Research complex II complements this with aspects of the health and well-being part of the group of applications. Automated usability analysis for smartwatch applications addressed in research complex III seems explicitly not have been the focus of research so far. However, it is a crucial success factor during the design and development of smartwatch applications since it directly impacts the acceptance of smartwatch-based IS.

5 Research Design

According to the overall concept of the doctoral program “Design of Mobile Information Systems in the Digital Transformation” (Muntermann et al. 2020), in which this work is embedded, the research design is based on the research paradigm of design-oriented business information systems and mobile information systems will be developed and evaluated. Thus, the context-specific requirements of users and organizations changed by the digital transformation will be considered, and a specific benefit for them will be achieved. The development and evaluation of IS have two different goals: (1) The generation of problem solutions that are beneficial for society and the economy, and (2) the acquisition of scientific knowledge. This combination is achieved through an approach that not only uses empirical research methods and theories but also emphasizes the cooperation and exchange between researchers and acting persons in practice. Finally, the scientific knowledge objectives of design-oriented business informatics represent prescriptive instructions for action and normative theories (design principles and design theories) of the highest practical relevance.

Hence, this thesis is positioned within the practice-orientated business information systems and, in particular, addresses the research domain of smartwatches in the corporate context. As illustrated in Figure 10, the thesis is embedded in the ongoing trend of digitalization of the workplace and particularly targets mobile information systems. From a technical view, smartwatches emerged in the class of wearable computers through the miniaturization of electronic components (Peercy 2000). From the economic view, the investigated socio-technical systems should address the new requirements with innovative IT-artifacts and, in particular, support employees during work. Thus, this thesis focuses on combining technical concepts with business management problems targeting the utilization of smartwatches in the corporate context.

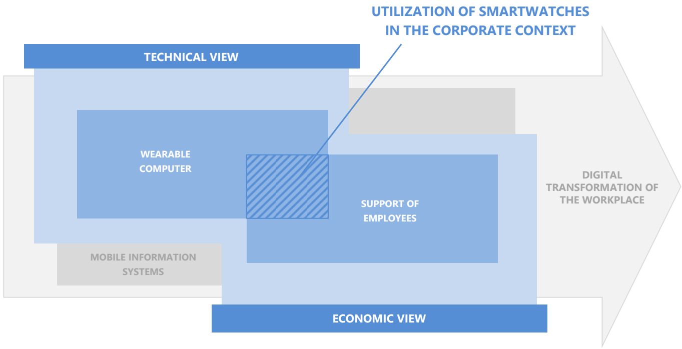


Figure 10. The positioning of the thesis

The focus is on the design of prototypical applications to gather design knowledge and derive design guidelines. Despite the design-oriented focus, also research methods are applied that are related to the explanation-oriented research paradigm so that the thesis follows the method-pluralism of business information systems. By the design-oriented approach, the thesis aims at a high practical relevance without neglecting the scientific contributions.

To address the objectives above and in section 2 formulated meta-research questions, Figure 11 illustrates the overall research design. As introduced in section 2, it is composed of three research complexes. In order to achieve the research objectives, a preceding literature review according to vom Brocke et al. (2015), vom Brocke et al. (2009), Fettke (2006), and Webster / Watson (2002) is conducted at the beginning as a prelude. Based on the results, the state-of-the-art can and resulting research gaps can be obtained. Since recent research has not focused on utilizing smartwatches in the corporate context so far, Hobert / Schumann (2018) conducted a workshop-series within an industrial production facility to elaborate on promising use cases for wearable computers. The main goal of these workshops was to identify application scenarios that are beneficial for both the employees and the company. The identified production scenario forms the basis for further investigations of this thesis. The set of use cases is gradually extended during the conducted empirical studies.

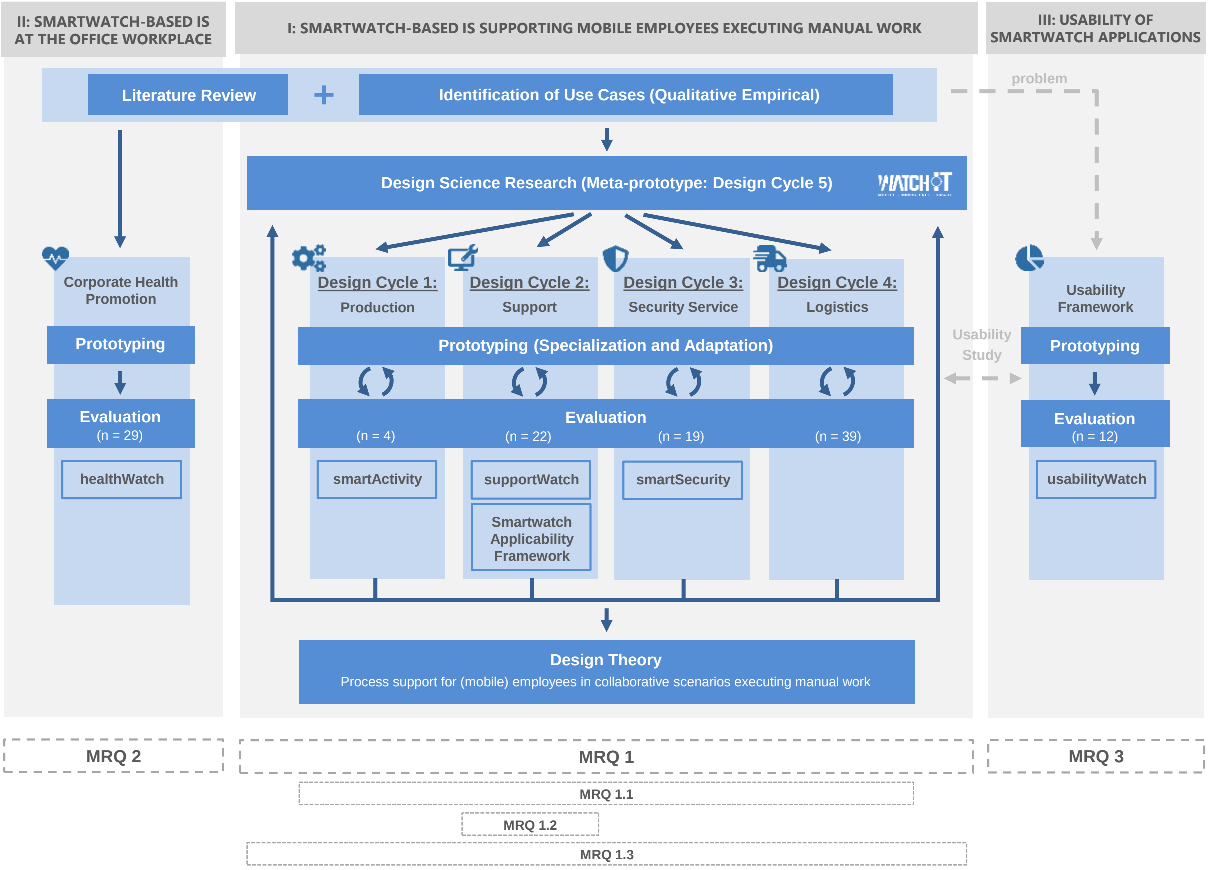


Figure 11. The research design of the thesis

Research complex I is the central component in this thesis and thus exhibits the most extensive research design. It is composed of a comprehensive design science research approach, including five design science research cycles, according to Gregor / Hevner (2013). The objective is to gather design knowledge during the iteration of four subsequent use cases identified during the literature review and the initial qualitative empirical workshop series. In each use case, the problem-oriented design science research model by Peffers et al. (2007) is applied. This comprises (1) problem identification, (2) objectives, (3) design and development, (4) demonstration, and (5) evaluation. (6) the communication is done with the publication of the individual studies in their particular research outlet (see Table 2). In the first cycle, a production scenario is analyzed, and the primary prototype *smartActivity* is implemented. It is evaluated relying on extensive interviews with two domain experts. Based on that, the software artifact is modified and extended in cycle two during a support scenario resulting in the *supportWatch* software-artifact. The evaluation is composed of a preliminary qualitative and quantitative questionnaire with 18 participants, a field study with seven participants over four weeks, a concluding questionnaire with five participants of the field study, and additional focus interviews with six participants. Besides the design and development of the software-artifact, the study contributes explanation-oriented to the theory of mobile IS, elaborating on enabling and inhibiting influences for the smartwatch adoption of smartwatches in companies. This results in the *Smartwatch Applicability Framework* and addresses MRQ 1.2. The third design science research cycle investigates a security service use case, and the *smartSecurity* system is designed and developed based on current knowledge. In two interviews and four workshops, including a demonstration and qualitative and quantitative questionnaires, in total, 19 domain experts evaluate the system. In the logistics use case, the software prototype is configured, and an evaluation study composed of a preliminary questionnaire to obtain application scenarios, and a concluding qualitative and quantitative questionnaire is conducted. In total, 38 domain experts participate in this study. Together, the situated artifact design for the use cases addresses MRQ 1.1. Finally, the findings are generalized in the fifth design cycle, the problem becomes a problem class, and design principles are elaborated. To document the obtained design knowledge, the *watchIT* software artifact is designed and developed, and a nascent design theory, according to Gregor / Jones (2007), is proposed. This addresses MRQ 1.3 and concludes the first research complex.

In research complex II, a smartwatch-based IS for corporate health promotion is designed and evaluated. For that, an approach inspired by the problem-centered design science process model of Peffers et al. (2007), including five steps, is applied. (1) In a problem identification phase, an extensible literature review is conducted. (2) With the employee at an office workplace as the identified subject of investigation, requirements as the solution’s objectives based on the literature are elaborated. (3) During a software development phase and prototyping, the smartwatch-based IS *healthWatch* is designed and developed. (4) Subsequently, the software-artifact is demonstrated within a realistic scenario to various decision-makers in corporate health management as domain experts. (5) In the evaluation, 29 employees at different office workplaces evaluated the IS during an online laboratory experiment with a qualitative and quantitative questionnaire. In this way, meta-research question 2 can be addressed.

Due to the request during the studies in research complex I and II of a method to access the usability of smartwatch applications, an auxiliary tool is built in research complex III. To investigate the research gap regarding dynamic usability analysis of smartwatch applications, a mixed-methods approach based on the problem-centered design science research process model by Peffers et al. (2007) composed of four steps is applied. (1) During the problem identification phase, a structured literature review is conducted to gain a holistic view of recent approaches regarding usability analysis on mobile devices, analyzing the possible adaption to smartwatch applications. (2) Matching the extent methods to the unique characteristics of smartwatches, objectives, and requirements for the next phase can be obtained. (3) During the design and development, the usability framework *usabilityWatch* is created. (4) Finally, during a usability laboratory experiment with 12 participants, the framework is implemented in the *smartActivity* application, and the results are evaluated by matching the human perception requested with a qualitative and quantitative questionnaire with the automatically generated usability insights. Altogether MRQ 3 can be addressed.

In Table 6, the thesis's scientific positioning is summarized, and the meta-research questions are further categorized.

MRQ		**Research-Paradigm**	**Research-Methodology**	**Theories and Models**
prelude		*explanation-oriented*	- Literature review	-
1	**1**	*design-oriented*	Design Science Research - Prototyping - Field study - Qualitative and quantitative questionnaires and interviews	- Cognitive Load Theory - Technology Acceptance Model
	2	*explanation-oriented*	- Field study - Qualitative and quantitative questionnaires and interviews	- Technology-Organization-Individual-Environment-Framework
	3	*design-oriented*	Design Science Research - Deductive reasoning	- Cognitive Load Theory - Media Synchronicity Theory - Information Foraging Theory - Technology Acceptance Model - Nascent Design Theory
2		*design-oriented*	- Literature review - Prototyping - Online laboratory study - Qualitative and quantitative questionnaires	- Self-Determination Theory - Goal-Setting-Theory - Cognitive Evaluation Theory - Technology Acceptance Model - Fogg Behavior Model
3		*design-oriented*	- Literature review - Prototyping - Laboratory study - Qualitative and quantitative questionnaires	- People at the Centre of Mobile Application Development Model

Table 6. Scientific positioning of the thesis

B Studies

In this part of the cumulative thesis, the individual research studies are presented. As illustrated in Figure 12, the studies are arranged in the research complexes (I) smartwatch-based IS supporting mobile employees executing manual work, (II) smartwatch-based IS at the office workplace, and (III) usability of smartwatch applications.

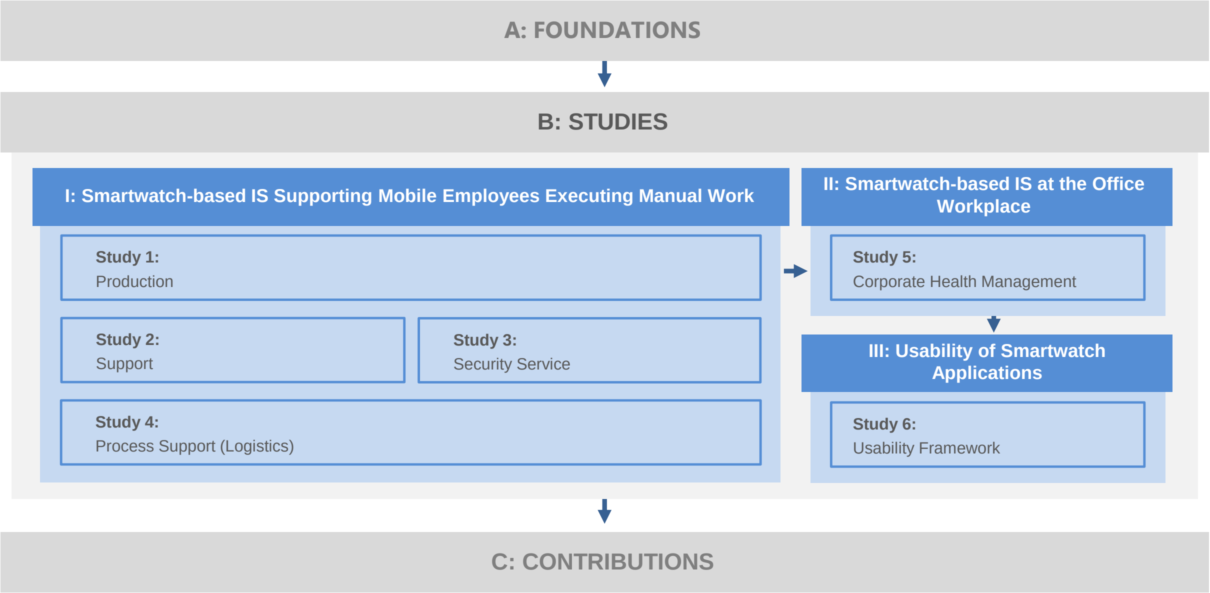


Figure 12. Structure of thesis' part B presenting the individual research studies

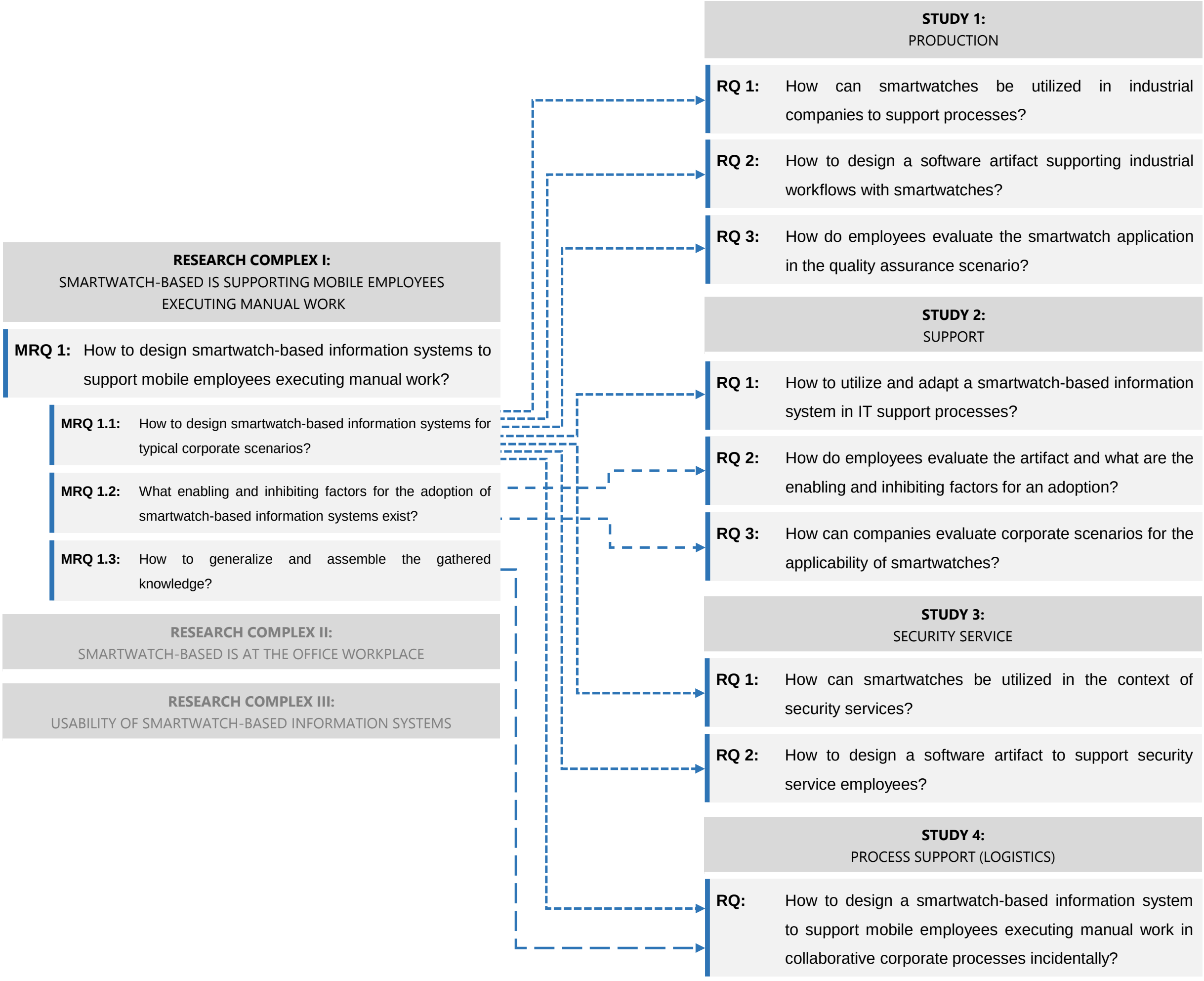
I Smartwatch-based IS Supporting Mobile Employees Executing Manual Work

To benefit from the full potential of the unique smartwatch device characteristics like ubiquity and incidental exchange of information and hands-free operation, this research complex addresses the support of mobile employees executing manual work with smartwatch-based information systems. The corresponding MRQ 1 that investigates how to design smartwatch-based IS to support mobile employees executing manual work is subdivided into three ancillary meta-research questions due to its extensive and central shape.

First, typical corporate scenarios are selected, and for each, the design of a situated smartwatch-based information system is studied (MRQ 1.1). As depicted in Figure 13, this MRQ is refined and addressed in four research papers. Zenker / Hobert (2019, study 1) investigate a production use case and examine how smartwatches can be utilized in industrial companies to support processes (RQ 1). Based on that, a software artifact to support industrial workflows is designed, developed (RQ 2), and evaluated in a quality assurance scenario (RQ 3). In the next research paper, Zenker et al. (2020b, study 2) survey on how to utilize and adapt a smartwatch-based IS in IT support processes (RQ 1). A security service use case is studied by Zenker (2020, study 3), the utilization in such a scenario is analyzed (RQ 1), and a smartwatch-based IS is designed to support security service employees (RQ 2). The last use case covered by Zenker et al. (2020a, study 4) describes a logistics scenario and provides an evaluation study. Summarized, four representative use cases are presented that are typical for the corporate context concerning mobile employees executing manual work and can readily be transferred to other similar scenarios.

Second, MRQ 1.2 focuses on enabling and inhibiting factors for the adoption of smartwatch-based IS by companies constituting technical, organizational, environmental, and individual prerequisites. For that, in the support use case (Zenker et al. 2020b, study 2), enabling and inhibiting influences of a smartwatch adoption by companies are obtained (RQ 2). RQ 3 assembles these influences into a framework that can be used to evaluate corporate scenarios of how smartwatches can be effectively utilized.

Finally, MRQ 1.3 aspires to a generalization of the individual use cases and recent findings. Therefore, Zenker et al. (2020a, study 4) summarize the previous studies to gather the obtained knowledge and to generalize the problem to the problem class of smartwatch-based information systems supporting mobile employees during manual work as well as the solution to the level of design principles (RQ). This is documented in a nascent design theory.



RESEARCH COMPLEX I:
SMARTWATCH-BASED IS SUPPORTING MOBILE EMPLOYEES EXECUTING MANUAL WORK

MRQ 1: How to design smartwatch-based information systems to support mobile employees executing manual work?

MRQ 1.1: How to design smartwatch-based information systems for typical corporate scenarios?

MRQ 1.2: What enabling and inhibiting factors for the adoption of smartwatch-based information systems exist?

MRQ 1.3: How to generalize and assemble the gathered knowledge?

RESEARCH COMPLEX II:
SMARTWATCH-BASED IS AT THE OFFICE WORKPLACE

RESEARCH COMPLEX III:
USABILITY OF SMARTWATCH-BASED INFORMATION SYSTEMS

STUDY 1:
PRODUCTION

RQ 1: How can smartwatches be utilized in industrial companies to support processes?

RQ 2: How to design a software artifact supporting industrial workflows with smartwatches?

RQ 3: How do employees evaluate the smartwatch application in the quality assurance scenario?

STUDY 2:
SUPPORT

RQ 1: How to utilize and adapt a smartwatch-based information system in IT support processes?

RQ 2: How do employees evaluate the artifact and what are the enabling and inhibiting factors for an adoption?

RQ 3: How can companies evaluate corporate scenarios for the applicability of smartwatches?

STUDY 3:
SECURITY SERVICE

RQ 1: How can smartwatches be utilized in the context of security services?

RQ 2: How to design a software artifact to support security service employees?

STUDY 4:
PROCESS SUPPORT (LOGISTICS)

RQ: How to design a smartwatch-based information system to support mobile employees executing manual work in collaborative corporate processes incidentally?

Figure 13. Refinement of the meta-research questions of research complex I

For each study, supplementary material is provided in the appendix. This includes the translated interview guidelines for study 1 in appendix 2, the translated questionnaire and interview guideline for study 2 in appendix 0, the translated questionnaire for study 3 in appendix 4, and the translated workshop guideline and questionnaires for study 4 in appendix 0.

1 Production

Design and Implementation of a Collaborative Smartwatch Application Supporting Employees in Industrial Workflows

DESIGN AND IMPLEMENTATION OF A COLLABORATIVE SMARTWATCH APPLICATION SUPPORTING EMPLOYEES IN INDUSTRIAL WORKFLOWS

Research paper

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Abstract

Due to new technological developments and the availability of affordable wearable devices like smartwatches, which recently hit the consumer market, employees in the corporate context can benefit from ubiquitous access to information. Especially in industrial production, there are complex and high involving workflows, which require the collaboration of multiple persons spread over different divisions. In such scenarios, fast and reliable communication is difficult and often disturbs work. Since smartwatches can be worn permanently on the body and the employee has non-disruptive access to information without the use of hands, such devices offer big potential for seamless support and guidance within a service system. In this paper, we identify a representative problem composed of a quality assurance process with practical relevance and design and implement an information system based on smartwatches in a design science approach. Since we infer meta-requirements for our system from the results of qualitative studies, the needs of employees are strongly considered and the developed software can be applied in a broad class of related problems. Finally, we evaluate the created meta-artifact in the identified scenario in order to obtain insights and knowledge about building information systems based on smartwatches for collaborative workflow support.

Keywords: smartwatch, industrial workflow, mobile information system, design science research, wearable computer, collaboration

Abstract: Due to new technological developments and the availability of affordable wearable devices like smartwatches, which recently hit the consumer market, employees in the corporate context can benefit from ubiquitous access to information. Especially in industrial production, there are complex and high involving workflows, which require the collaboration of multiple persons spread over different divisions. In such scenarios, fast and reliable communication is difficult and often disturbs work. Since smartwatches can be worn permanently on the body, and the employee has non-disruptive access to information without the use of hands, such devices offer big potential for seamless support and guidance within a service system. In this paper, we identify a representative problem composed of a quality assurance process with practical relevance and design and implement an information system based on smartwatches in a design science approach. Since we infer meta-requirements for our system from the results of qualitative studies, the needs of employees are strongly considered, and the developed software can be applied in a broad class of related problems. Finally, we evaluate the created meta-artifact in the identified scenario in order to obtain insights and knowledge about building information systems based on smartwatches for collaborative workflow support.

Keywords: Smartwatch, Industrial Workflow, Mobile Information System, Design Science Research, Wearable Computer, Collaboration

Citation: (Zenker / Hobert 2019, study 1) Zenker, S.; Hobert, S.: Design and implementation of a collaborative smartwatch application supporting employees in industrial workflows. In: Proceedings of the 27th European Conference on Information Systems (ECIS) 2019, 1–16.

1.1 Introduction

Due to new technological developments (Lasi et al. 2014) and the availability of affordable mobile devices during the progress of digitalization in the last decades, employees can benefit from ubiquitous access to information within the corporate context (Schmidt et al. 2015). New aspirations have been observed in recent years to improve industrial service systems and processes to gain a competitive advantage by the use of cyber-physical systems (Gorecky et al. 2014). In order to support employees in complex and high involving workflows, mobile information systems have to satisfy several requirements to yield more flexibility. Many dynamic processes in the industrial sector (e.g., production processes) necessitate that employees are neither restricted in their freedom of movement nor are occupied with hand-held devices like smartphones or tablets (Kortuem et al. 1999). In the last couple of years, the class of wearable computers emerged and entered the consumer market, which allows the users simultaneously to gain access to their digital workplace and to use their hands to interact in their work environment, e.g., utilizing tools or operating machines (Billinghurst / Starner 1999). These properties are in particular met by smartwatches, which are permanently available, easily observable, unobtrusive, easy to use and carry along on the body, allowing almost hands-free operation especially for receiving information (Ziegler et al. 2015) and thus have the potential to be used for mobile process support (Hobert / Schumann 2017a).

However, scientific research focused little on the advantages of smartwatches supporting workflows. Since employees are an important economic factor, a collaborative and employee-centered approach can significantly increase economic success by reducing the workload (Ziegler et al. 2014), keeping the system simple, as manual work is strenuous and has higher priority than interactive tasks (Boronowsky et al. 2001). Thus, the aim of our approach is to offer support and guidance for employees improving communication, time management, and spent effort.

With the superordinate intend in this paper to understand how smartwatches can be deployed to support processes in the corporate context, a software artifact is developed, evaluated, and discussed in order to address a problem originating from industrial practice. In this particular case, a service workflow composed of the interaction between machine operators and a quality assurance division is considered. The quality assurance division offers a company internal service to continually test currently produced parts for harmful deviations. For widely spread employees, fast and effective communication is difficult, especially during manual tasks (e.g., repairing a machine). We provide and describe a socio-technical meta-artifact suited to target a broad class of related problems, which is then applied to the particular quality assurance scenario. Since quality assurance is an integral part of the production, employees of both departments have to collaborate, and digitalization of this service system (Beverungen et al. 2018) improves value co-creation through direct ubiquitous communication and access to information. Beyond smartwatches in the consumer sector, this novel approach should illustrate the potential of smartwatches supporting workflows in the corporate domain, so far mostly unexplored in research.

Furthermore, it should encourage entrepreneurs to use these findings in their companies and aside facilitate employees' daily work.

In order to target this practice-orientated research problem within the industrial sector, we follow the design science research approach (March / Storey 2008). We propose a research design strongly inspired by Peffers et al. (2007), including problem identification, deduction of objectives, design process, demonstration, and finally evaluation to implement and evaluate an application for smartwatches. Thereby, we provide a level 1 design science contribution according to Gregor / Hevner (2013) by creating a situated implementation of an artifact for the introduced problem, provide the foundation for level 2 with a meta-artifact approach and address the following three research questions:

RQ1: How can smartwatches be utilized in industrial companies to support processes?

RQ2: How to design a software artifact supporting industrial workflows with smartwatches?

RQ3: How do employees evaluate the smartwatch application in the quality assurance scenario?

To answer these research questions, the remainder of this article is structured as follows: First, we present definitions of basic terms and outline related research and practice in section 1.2. Second, we describe our research method based on the design science research framework of Peffers et al. (2007) in section 1.3. By applying the framework to our problem domain, we illustrate the results of our design science approach in section 1.4. Finally, we discuss our findings and outline our research contributions for theory and practice in section 1.5.

1.2 Related Research and Practice

Smartwatches can be defined as a special form of wearable computer devices in the shape of digital watches equipped with various sensors and wireless interfaces (Cecchinato et al. 2018). As all wearable computers, they are worn on the users' body and are therefore always available to the users – independently of a specific location or time (Boronowsky et al. 2008; Rhodes 1997). Due to the location on the users' wrist and the possibility to provide haptic feedback (e.g., vibrations), smartwatches can proactively demand the users' attention. Thus, they can immediately initiate interactions with users, e.g., when it receives an important notification. Technically, smartwatches are similar to mobile devices due to their hardware components. However, the use cases differ: wearable computers and especially smartwatches are usually limited to simple input and output options due to the small form factor (Malu / Findlater 2015). Nevertheless, because of the fact that users are wearing the devices, they can always interact with them. In contrast, mobile computers offer more advanced input and output capabilities (Chaparro et al. 2015), but they can only be used when users get them out of their pockets and hold them in their hands.

Research on wearable computers started more than 50 years ago (Thorp 1998; Rhodes 1997). Whereas in the past, most research contributions targeted technical aspects like constructing wearable hardware devices or extending its capabilities (Xiao et al. 2014), recent research focusses more on (1) designing software applications, (2) actual applications in private or business contexts as well as (3) the added value of wearable computers (Berkemeier et al. 2019; Hobert / Schumann 2017b; Bieber et al. 2013). For instance, Lukowicz et al. (2007) stated that wearables could be used for information, guidance, and instructions in maintenance tasks. Aromaa et al. (2016) studied wearable and augmented reality technologies in industrial maintenance work and tested the usefulness for technicians. Zheng et al. (2015) elaborated a wearable solution to offer guidance to the user, to support hands-free operation, and to enable collaboration with a remote expert in industrial maintenance. Furthermore, there are several contributions introducing concepts for the use of wearable computers that mostly focused on maintenance (Witt et al. 2006; Nicolai et al. 2005).

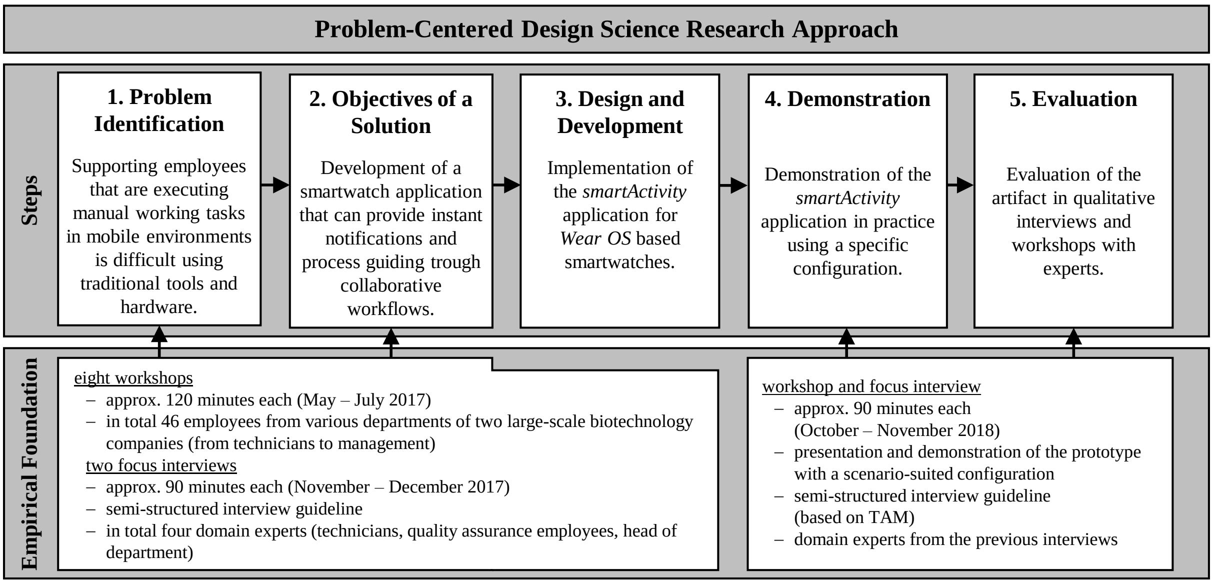
Nevertheless, research on using smartwatches is limited. Only a few contributions exist that researched specific application scenarios in the business context. For example, Awan et al. (2018) use smartwatches for nurse documentation by voice recognition, or Li et al. (2015) exploit smartwatch sensors to detect drowsiness of drivers. Villani et al. (2016) discuss the gestures interaction with smartwatches in situations where the touchscreen cannot be used, e.g., when wearing gloves or having greased fingers. Aehnelt / Urban (2014) provide a theoretical model for systematic information transfer between assistance systems and workers. Ziegler et al. (2015) investigated smartwatches to support mobile industrial maintenance tasks as a complementary user interface. Schönig et al. (2018) presented a toolset for an IoT-aware business process execution system to integrate smartwatches as an internet of things device into a business process management system. However, this system lacks facilitating features for the employee as step-by-step workflow guidance and collaborative support.

Nevertheless, there exist many open research gaps, e.g., (1) application scenarios that are beneficial for enterprises are missing, (2) design knowledge is required to implement proper smartwatch applications, and (3) usability aspects are unsolved. In many cases, only demonstration prototypes are produced and evaluated during experiments with participants lacking in practical experience.

Since the application of smartwatches is promising in the industrial context and offers multiple benefits for companies, there are already some commercial products available. *MeisterTask* (MeisterLabs GmbH 2020) is a best practice web-based project and task management tool for teams providing desktop, tablet, and smartphone interfaces enhanced with smartwatch compatibility. Besides the adoption of established mobile approaches, there are also smartwatch-centered products, which are directly designed for the device and an industrial scenario. The *Hipaax TaskWatch* (Hipaax LLC 2020) is a corporation with *Samsung* and combines scenario-fitting smartwatch devices with a construction kit for corresponding applications, including gamification aspects (Deterding et al. 2011). *aucobo* (aucobo GmbH 2020) offers interaction of workers and machines on the shop floor using a robust smartwatch equipped with a QR code scanner. *WORKERBASE* (WORKERBASE GmbH 2020) is a rugged smartwatch specifically designed for industrial use (including a QR code scanner) combined with a platform for manual tasks that need to be completed on the shop floor. However, these products either lack an adequate interaction in the smartwatch component, add more complexity for the employees, do not consider collaborative aspects, do not provide workflow support and guidance, have a limited range of functionality, or do not provide any scientific background. These products are the first entries in this sector and are not widespread so far. Thus, a design science research approach can provide a theoretical and research-based foundation to consider the needs of companies and employees.

1.3 Research Design

To target the research gap outlined in section 1.1, we applied a mixed-methods approach based on the problem-centered design science research process model by Peffers et al. (2007), as shown in Figure 14. In terms of Iivari (2015), we utilize the inductive strategy to develop an artifact for a specific problem encountered in practice and then generalize it to address a class of problems.



1. Problem Identification
Supporting employees that are executing manual working tasks in mobile environments is difficult using traditional tools and hardware.

2. Objectives of a Solution
Development of a smartwatch application that can provide instant notifications and process guiding trough collaborative workflows.

3. Design and Development
Implementation of the *smartActivity* application for *Wear OS* based smartwatches.

4. Demonstration
Demonstration of the *smartActivity* application in practice using a specific configuration.

5. Evaluation
Evaluation of the artifact in qualitative interviews and workshops with experts.

eight workshops
- approx. 120 minutes each (May – July 2017)
- in total 46 employees from various departments of two large-scale biotechnology companies (from technicians to management)

two focus interviews
- approx. 90 minutes each (November – December 2017)
- semi-structured interview guideline
- in total four domain experts (technicians, quality assurance employees, head of department)

workshop and focus interview
- approx. 90 minutes each (October – November 2018)
- presentation and demonstration of the prototype with a scenario-suited configuration
- semi-structured interview guideline (based on TAM)
- domain experts from the previous interviews

Figure 14. Research design with the respective empirical foundation

According to the process model, the artifact development should be grounded in the problem identification phase (step 1). To this aim, we rely on the results of a series of workshops that we conducted in summer 2017 within an industrial production facility. The main goal of these workshops was to identify application scenarios that are beneficial for both the employees as well as the company. After discussing and evaluating the resulting application scenarios, we chose to focus on smartwatches to support manual working tasks in industrial workflows like quality assurance processes (see section 1.4.1). In order to get more detailed insights, we conducted additional focus interviews with domain experts involved in the selected scenario.

With this quality assurance scenario as the identified real-world problem, we derived functional requirements as the objectives of our solution (step 2). For this purpose, we carefully analyzed the documentation of the workshop series and extended it with two focus interviews in November 2017. During these interviews, the questioned employees explained in detail how they are currently carrying out their work tasks and how they believe that smartwatches can support these workflows. Using this approach, we finally acquired nine meta-requirements that are the basis for the subsequent design cycle.

Following the design science research process model, we implemented a prototypical meta-artifact called *smartActivity* based on the deduced meta-requirements (step 3). By choosing an agile development approach, we were able to discuss intermediate prototypes regularly and improved them constantly until they met all mandatory functional meta-requirements.

Subsequently, we did a demonstration according to (Peffers et al. 2007) in step 4. For this, we have demonstrated *smartActivity* during a workshop and an interview, including the presentation of a realistic configuration for the quality assurance application scenario in order to apply the meta-prototype.

Finally, we checked the suitability for the given use case in an evaluation by comparing the task characteristics of the application scenario with the developed artifact and analyzing the feedback of the conducted workshop and interview based on the Technology Acceptance Model (Davis et al. 1989).

1.4 *smartActivity* Application

In this section, we present the design of the *smartActivity* meta-artifact to support industrial workflows with smartwatches and to provide a solution that can be applied to address the quality assurance scenario.

1.4.1 Problem Identification

Consecutive to a workshop series targeting the capabilities of wearable computers in the industrial context, we identified a process within the daily work in production. The foundation of our examined problem is shaped by the interactions of employees within industrial production and quality assurance workflow. Several workers are responsible for machines in a certain workshop, which are used to produce components for later assembled technical products. These are predominantly mills converting blocks of metallic raw material into complex structured elements. Each worker operates a group of machines, which have to be programmed, equipped, and maintained. A crucial aspect is that the machines are located at different locations of the workshop. Due to the fact that the various milling-tools used in the automated machines wear out over time, the produced components can become inaccurate. In order to avoid assembly deficiencies, the components have to be checked and tested periodically by an employee of the quality assurance division.

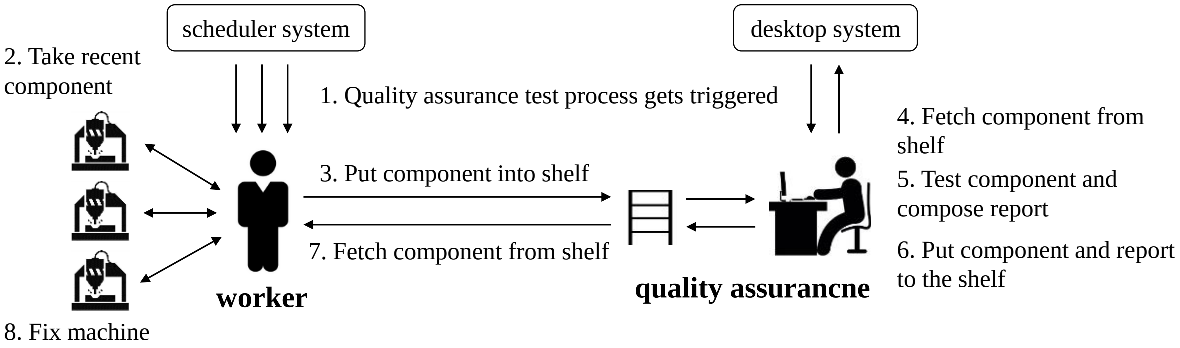


Figure 15. Current quality assurance workflow

As shown in Figure 15, the service workflow is composed of several human-to-human and human-to-machine interactions. In the background, a scheduler system tracks and manages the pending quality assurance test jobs. These requests can also be triggered by persons or sensors. Once a quality assurance test job of a certain component is due, the responsible worker takes a recently produced component from the desired machine. Next, the worker has to walk through the workshop and deliver the component to the quality assurance office. For this, the worker puts it on top of a destined shelf. Employees of the quality assurance division have to monitor this shelf periodically and successively handle every component which arrives. After completing the testing procedure according to the specifications, the component is put back on the shelf, and a paper-based test report is attached. This report is composed manually in a desktop-based computer station and contains all relevant information. The worker at the machine can use this information to draw conclusions about the tool conditions. Finally, the worker has to check the shelf periodically and fetch all processed components. Under the directive of the report, the worker can fix the machines tools if required.

Apparently, this workflow offers the potential for improvement through digitalization due to two key problems. On the one hand, there is uncertainty for all involved persons when a task of the counterpart is completed. Since the workers move between the assigned machines and the shelf in order to periodically check whenever components are processed, long footpaths occur. Due to this fact, a machine with worn tools could produce a lot of inaccurate components until an already measured component is fetched from the shelf. This results in an unnecessary waste of time, raw material, and money, respectively. In addition, tardily or completely undiscovered variances can lead to some serious damage for the machine. On the other hand, there are media disruptions varying between digital, printed, and written representations of the same information. First, an employee of the quality assurance division has to put the component id into the computer system. Then, the digitally obtained protocol during the quality assurance test process is printed again and handed over to the worker who has to read and interpret it correctly. Merely, if the worker discovers any variances, the details can be checked at a desktop PC, which is mounted at the machine.

1.4.2 Objectives

Since in prior research, information systems, including a smartwatch application for the industrial context, are sparsely addressed in a collaborative employee-centered approach, we conducted qualitative interviews with several domain experts.

The primary idea was to digitally support the service system of production and quality assurance collaboration, including human-human and human-machine interactions. The first functional requirement is to provide status reports of machines for the responsible worker. So far, a traffic light system exists, which shows the state of the machine and particularly a red signal whenever an error occurs. The disadvantage of this system is that the workers are widely distributed within the workshop, and they cannot see the signals all the time. Beyond, acoustical signals are a bad choice because the environment is very noisy. *“It is enough to indicate whether a malfunction exists at a particular machine or not”* (expert 1). In the case a malfunction appears, the responsible worker should be immediately and location-independently informed without interrupting work. Furthermore, *“workers in the vicinity should also be notified to intervene quickly if necessary”* (expert 1). For this, a group of workers has to be addressed simultaneously.

After the identification of the problem described above, the list of requirements extends. *“Machine downtimes can be avoided, and the quality would raise if the worker gets notified whenever a components quality assurance test is concluded”* (expert 1). This implies a message *“component measurement done”* (expert 2). Once a message was received, the employees of the quality assurance division want to have small feedback like *“got the information”* (expert 2) to make sure that possible fatal malfunctions are treated. Some cases require an immediate stop of a machine otherwise, *“100 % waste is produced”* (expert 2) in the meantime, and a lot of money is dissipated. After a worker has received a notification and took care of the issue, the worker should *“easily wipe the notification away”* (expert 3) and indicate the concern as completed. On the other side, at the quality assurance division, it should be possible to input test results. *“The measuring program could be designed in such a way that the data is automatically entered into the system, or by the employee operating the machine”* (expert 1). Since there is no interface, this remains a manual task, and the relevant information has to be compiled by hand. To identify the quality assurance test job, at least *“part number and machine number must also be included”* (expert 1). In order to provide a recommendation for action, a survey of quality assurance test results, including characteristic numbers, should be attached to the notification. *“Not all measurement data would have to be transmitted at all, one ‘okay’ is enough, if everything is within the bounds”* (expert 3). More precisely, it should be distinguished between *“all right and not all right”* (expert 2), and the worker can later take a look at the full report at the terminal located at the machine. Due to the small display and the limited capabilities of a smartwatch for displaying a lot of text, *“relatively little information should be transmitted there”* (expert 2). To solve this, *“in the best case, only the dimensions where deviations exist should be displayed”* (expert 2). For further improvements of the quality, there should be a statistic, which tracks the errors for each machine respectively to figure out *“how often which error occurs”* (expert 2).

Finally, there are several non-functional objectives, which refer to the used hardware or other legal regulations. Relating to the battery life of a smartwatch, *“we have two shifts so the battery should last 24 hours”* (expert 1), but *“eight to nine hours is a real must because this is one shift”* (expert 2). A smartwatch should be used for a working shift without any interruption and can be charged afterward. In terms of robustness, *“the smartwatch, including the wristband, should be impact-, water-, oil- and acid-resistant since we are dealing with machines and aggressive liquids”* (expert 2). *“In addition, we need protection against electronic discharge in the assembly department”* (expert 1). The hardware of the smartwatch should offer several protections against environmental influences, especially occurring in the industry. Since *“we do not need any employee-related information like a name or id”* (expert 1 and 2) and the tracking and processing of this information are not allowed in a lot of companies due to the European general data protection regulation, smartwatches are addressed by their respective related functional workplace.

We summarize all described requirements in Table 7, being the foundation of the next section where the requirements are generalized and implemented in our artifact.

Functional requirements			
worker	**FR$_1$**	Display alerts of machines	immediate and independent of location
	FR$_2$	Notifications of concluded QA jobs	
	FR$_3$	Acknowledgment of received notifications	
	FR$_4$	Display aggregated QA test reports	
QA	**FR$_5$**	Input of QA test reports	
	FR$_6$	Provide error statistics over time	

Non-functional requirements	
NFR$_1$	At least 8 hours of battery life
NFR$_2$	Protections against environmental influences (impact, water, oil, acid, and electronic discharge)
NFR$_3$	No acquisition of employee-related data

Table 7. Functional and non-functional requirements

1.4.3 Design and Development

In order to meet these specified objectives, we designed and developed the software meta-artifact *smartActivity*. Since FR1 – FR4 necessitate immediate and location-independent access to information, we deploy smartwatches in the mobile parts of the system in order to ensure seamless and uninterrupted use. We want to provide a solution, which can be applied in numerous situations and various scenarios. Thus, previously to the implementation, an abstraction step is done. This allows us to yield a more flexible approach, which is easily applicable and not overloaded. Therefore, we deduce meta-requirements based on the results of section 1.4.2 listed in Table 8.

Functional meta-requirements					
desktop backend	**FMR$_1$**	Manage devices	smartwatch	**FMR$_7$**	Receive task notifications hands-free
	FMR$_2$	Manage workstations		**FMR$_8$**	Send immediate task acknowledgments
	FMR$_3$	Manage workflows		**FMR$_9$**	Provide workflow guidance
	FMR$_4$	Create activities			
	FMR$_5$	Display and respond to tasks according to workflows			
	FMR$_6$	Provide statistics			

Table 8. Functional meta-requirements

In order to generalize the problem presented in section 1.4.1, we prescind the roles of workers and employees of the quality assurance department to mobile and stationary workspaces. Hence, all integrated devices are identified by workstations and can either use the mobile software component (e.g., smartwatches), the backend (e.g., desktop PC), or both (e.g., smartphones or tablets). Consequently, an administrative element has to manage devices and assign workstations to them. In addition, we want to design a meta-system beyond quality assurance processes and allow any kind of workflow. Thus, the administrative component can build workflows, including underlying tasks. Using these workflow templates, the system can create activities that are an instance of a workflow and can guide employees through a collaborative process. A core requirement is to handle the dedicated tasks of an activity. Tasks are displayed, and subsequent actions are generated and respectively triggered after the recent step is processed. In the case of the mobile software component, notifications of incoming tasks are released, and an acknowledgment is sent once the notification is confirmed. Furthermore, the mobile component offers workflow guidance while reducing displayed information to the necessary and required inputs to a minimum due to small device displays. We present our overall system architecture in Figure 16.

There are three key components: (1) a native *Android Wear OS* based smartwatch application, (2) a web component, which can be operated using a browser on a desktop or mobile device, and (3) a server, which operates the whole system offering all interfaces and containing the database. An enterprise wireless network is used to connect all components in a fast, reliable, and secure way. As confidential information like machine and workflow states are exchanged, no further online service is involved. Additionally, in this way, it is not possible for external devices to connect to the system and disturb the process. Furthermore, this infrastructure is more failure-prone and does not depend on the availability and future compatibility of other services.

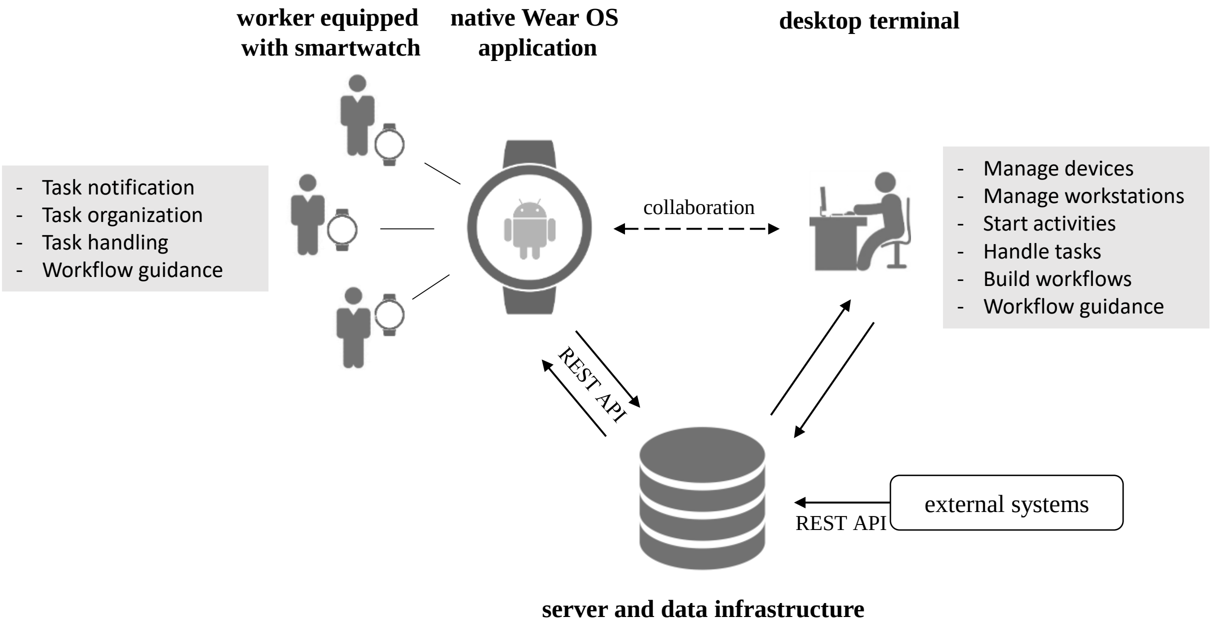
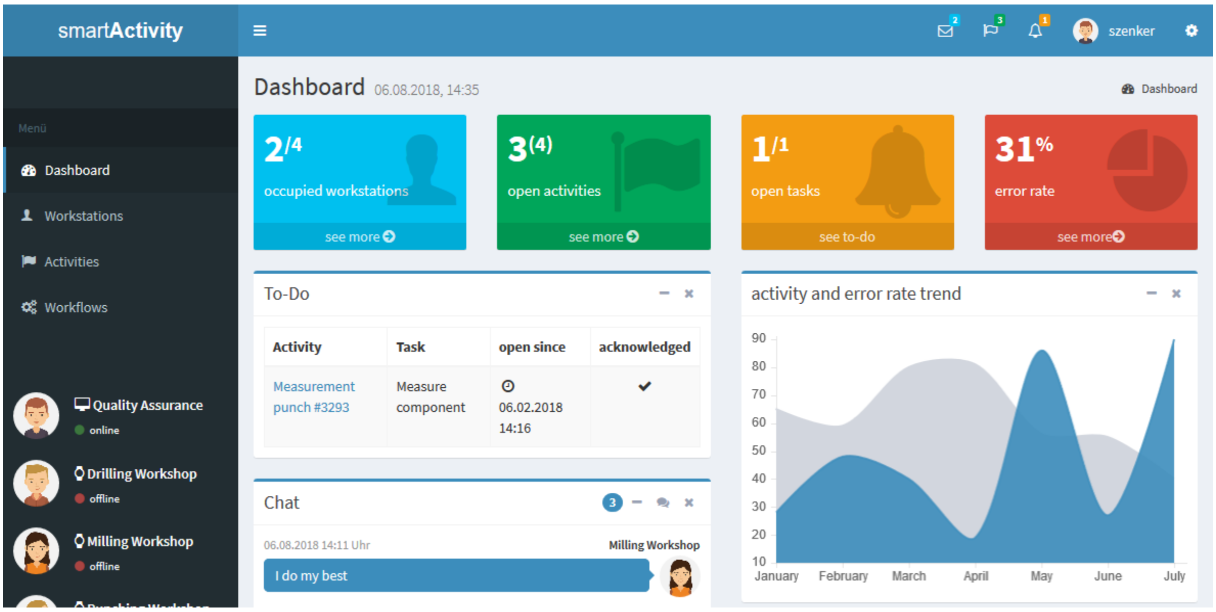


Figure 16. *smartActivity* system architecture

For the server component, we use PHP to benefit from its abilities related to web applications. In this way, the desktop terminal is empowered with modern web technologies like HTML5. The smartwatch application is integrated using a provided REST interface. In addition, this interface can be utilized to receive information from other systems like a scheduling system mentioned in section 1.4.1 or event triggering sensor data. For data storage, we choose a relational MySQL database. We selected well known and approved technical approaches at the server-side in order to ensure easy applicability in practice.

The web-based component is the backend of the *smartActivity* application and is displayed in a browser. It allows employees to manage and supervise all processes on a stationary device, like a desktop PC or mobile devices, like a tablet or a smartphone, which ensure an adequate overview with decent display size. In order to protect the system from unintentional access, it requires a login, including a password. In general, *smartActivity* addresses workplaces (e.g., quality assurance employees) instead of persons with their respective names in order to protect them against observation and tracking. Once logged in, every user has an own dashboard containing all actual relevant information. For a quick overview, critical factors, like the occupied workstations, open activities, open tasks, and some statistical analytics are shown. Furthermore, a list of pending tasks is provided. A screenshot of the dashboard is given in Figure 17. In the first step, all mobile devices can be registered in the backend. In our case, we just use smartwatches in the mobile domain, but because there is no technical limitation to smartwatches, every device can be integrated. Besides, workstations can be managed (created, edited, and deleted), including a name and a description. Once this is done, every workstation can be assigned to a previously connected device and can now be addressed by its workplace name.



Activity	Task	open since	acknowledged
Measurement punch #3293	Measure component	06.02.2018 14:16	✓

06.08.2018 14:11 Uhr

Milling Workshop

I do my best

Figure 17. Dashboard of the web-based component

The key functionality of *smartActivity* is to manage activities and their subordinated tasks. Our application provides two different ways to create activities. On the one hand, a custom activity using a name, description, first task, and the intended workplace can be defined. This enables full flexibility of the covered process. However, every successive task has to be customized with a name, description, and receiver accordingly, which is not reasonable due to the very limited capability of text input on smartwatches. On the other hand, an activity can follow a predefined workflow to guide an employee through all steps. In favor, our application provides a workflow editor where arbitrarily shaped workflows can be compiled. The workflow builder is shown in Figure 18.

Successively, the steps within a workflow can be added, starting with a primal task (red) towards the final tasks (green). It is also possible to edit and remove steps. Furthermore, alternative flows can be implemented, which are indicated by multiple nodes in the same level of the tree. Workflows then are traversed from top to bottom, and the employee can choose the adequate path respectively from one step to the next one. In Figure 18, a possible workflow for the scenario presented in section 1.4.1 is given. Once an activity, according to this certain workflow is created, a “provide component” task is generated and sent to the selected workplace. Until a final task, e.g., “no complaint” is reached, the involved workstations are informed respectively.

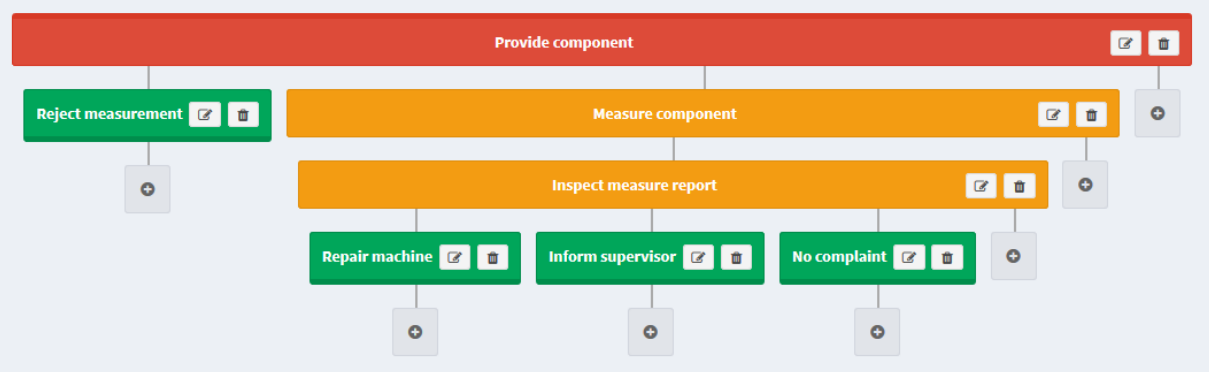


Figure 18. Workflow builder showing a quality assurance scenario suited workflow

The smartwatch application is the mobile component of *smartActivity.* It is built as a native *Android Wear OS* application since this operating system is the only commercial system that is used by multiple vendors and covers almost 40 % of the smartwatch market (Statista 2019). In addition to the wide range of smartwatch models, it has the advantage that such an application can run on every wearable computer (e.g., smartglasses) with *Wear OS,* and only the graphical interface has to be revised. In order to use the full potential of mobility, this is developed as a standalone application, which does not require any connected smartphone and is executed on the smartwatch itself (Google and Open Handset Alliance 2020). The application consists of three major screens shown in Figure 19. Whenever the application is started on a smartwatch, it connects to the server and establishes communication calling the REST interface. For a newly connected device, it does the registration negotiation automatically in order to be assigned to a workplace. If the device is registered, it retrieves the relevant data from the server, including the actual list of tasks. In the main menu of the smartwatch application, which can be accessed using a wiping gesture, the list of tasks, statistics, received messages, and settings can be reached. As soon as a new task arrives, it is added to the task list, and a notification appears (see Figure 19 (1)). The combination of the visual and tactile perception is used to ensure the attention of the employee, who can either acknowledge or postpone the notification. The most active element is the list of activities (see Figure 19 (2)). Here an employee can quickly survey all tasks that are assigned to the workplace. In order to react to a task, it can be selected in the activity list with a tap, and all the task details as activity name, name of the workstation involved in the previous workflow step, timestamps and all respective possible next steps are shown (see Figure 19 (3)). When the actual task is done, the employee can confirm it by selecting the next state in the process from respective options, which are automatically suggested regarding the defined workflow. Furthermore, the receiver of the next task is determined automatically. Apparently, the functionalities and the amount of displayed information on the smartwatch application compared to the desktop backend are strictly limited facilitating the usability of the application.

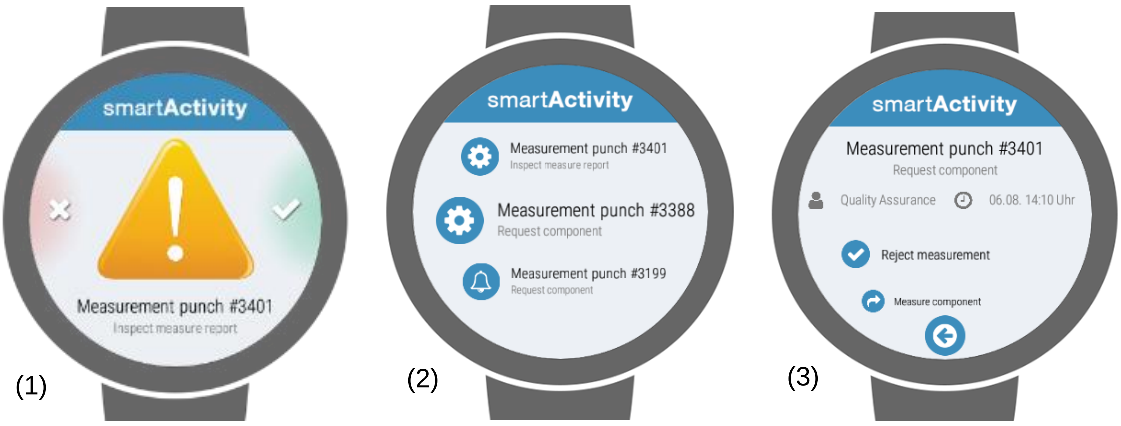


Figure 19. Screens of the meta-prototype, configured for the quality assurance scenario

1.4.4 Demonstration

After we have presented the design of the *smartActivity* application, we demonstrated it to domain experts. For this, we conducted a workshop with experts within the industrial context. Since we did an abstraction step and designed the artifact for adoption in a broad application area providing much functionality, the crucial point is to show and highlight the relevance of the solution in practice. For this, we created a workflow that covers the collaboration process between workers operating machines and employees of the quality assurance division shown in Figure 18. Independently of the particular trigger (a scheduler system respectively a sensor using the REST interface or a human at the desktop backend), the activity starts with the task “provide component”, which appears on the worker’s smartwatch who is responsible for the desired machine and encourages him to deliver a recently produced component to the quality assurance office. The worker has the option to quit the process with “reject measurement” in senseless situations or to deliver the component and return the next task “measure component” to the employee of the quality assurance division. Since the system is able to handle acknowledgments and can postpone tasks, the employees of the quality assurance division can dispatch their requests as habitual. As soon as the particular component is measured and the report is gathered in the desktop system, the employee puts back the component to the shelf and notifies the worker with the “inspect measure report” task. In addition, all relevant information about the result can be attached so that the worker knows immediately whether there are disturbances or not. Furthermore, these aggregated values are used in the background to build error statistics over time. According to the transferred report, the worker can finish the workflow with “repair machine” or “inform supervisor” in the case of deviations or with “no complaint” otherwise. In this way, the worker can save long and frequent footpaths, information flow is much faster, and media disruptions are eliminated.

In this case, we find it reasonable to use smartwatches for the workers and the desktop backend for the quality assurance division. Workers require a mobile device since they have to move through the workshop, use their hands to operate the machines, and it would be difficult to spend attention to handheld or other displays. They benefit from the direct visual and tactile notifications and the aggregation of quality assurance test results, which makes it easy to draw fast conclusions. As employees of the quality assurance division have to input and to deal with a lot of data, a desktop PC is a good choice for this side. Observing the acknowledgments, they can make sure that quality assurance test results are perceived, especially in critical situations in which damage to a machine impends. Both collaboration parties are guided through the process according to the defined workflow, and there are several decision options available for the different circumstances.

1.4.5 Evaluation

After we have demonstrated our solution to practitioners, we conducted a workshop and qualitative interviews to get feedback from experts. First, we want to discuss how the identified requirements are adapted to the presented artifact. Second, the results of the workshop and interviews are analyzed.

In the domain of functional requirements, all identified points are addressed. Alerts of machines (FR_1) can be displayed in such a way that a minimal workflow with two tasks, “check machine alert” and “done” is defined, and the triggering system calls the provided interface to populate the new activity, including the responsible person. Consequently, we allow every source of activity creation, which makes the system very flexible and easy to integrate into other system landscapes. As already shown in section 1.4.4, we implemented notifications for concluded quality assurance test jobs (FR_2). In general, notifications are shown whenever a new task of an activity appears in the task list. With the combination of visual and tactile stimuli, we make sure to get the attention of a person without interfering with work. Through acknowledgments, every participating person is informed about whether the counterpart has perceived the notification or not (FR_3). The input of quality assurance test reports (FR_5) can be done in the desktop component, where the data can be attached during the task creation process. In this way, it is possible to either display a green or a red notification indicator. Accessing this information at the detail page on the smartwatch makes it possible to inspect the aggregated quality assurance test report easily (FR4). In the background, statistics are built using the logged data, and overviews are created, which helps the employees to obtain insights for future organizational improvements (FR_6).

Since most non-functional requirements are hardware related and depend on the selected device, only NFR_3 is investigated here. *smartActivity* prohibits the tracking of person-related data. Devices are assigned to workplaces, and hence the corresponding employee cannot be directly retraced. Furthermore, no information of hardware sensors like GPS positions, gesture recognition using the accelerometer, or any chronometry is logged and analyzed. This ensures conformity with the European GDPR and improves the trust of employees in this new technology. We want to point out that this mobile information system is user-centered and should lead to more assistance and flexibility in an employee’s daily work.

During the workshop and interviews, several positive, as well as some critical points, were discussed. As we have expected, due to the abstraction step of the requirements identified in section 1.4.2 and formulating meta requirements, the practitioners just use a small fraction of functionalities provided by the system. *“Now I see the possibilities that you actually have with such a system. Because with it, I can theoretically control employees throughout the factory, distribute orders and so on”* (expert 4). In spite of the big extent, they gave the feedback that our solution fits their situation and improves recent vulnerabilities, including media disruptions, unnecessary footpaths, and avoidable misproduction. Apart from competitive advantages through revised workflows for the company, mostly the employees benefit from such a system. Communication in relation to collaborative procedures is easy and fast using a device worn on their bodies. This reduces footpaths, especially in considerable mobile fields of activity. It is important that the new system is uninterruptive, intuitive, and does not add more complexity to the actual work to minimize the workload put on the employee.

Two main contributions are identified by the experts within our scenario. First, *“we expect several things using our recent scheduler system from our employees for years, but it is completely in the background as far as the employees like to use it. Now we bring it forward with a watch and make it more mandatory in a supporting and guiding way”* (expert 2). Casual processes and information systems gain more importance since they are integrated into a mobile workplace in a superior way. When these are perceived as useful, the full potential can be capitalized. Second, *“it is quite clear that quality is most important to us, and with that system, I definitely increase the quality”* (expert 2). Since quality leads to economic success, such a system is profitable for a company.

And yet, the requirements identified in section 1.4.2 are fulfilled. It is possible to exchange notifications between the stationary employees of the quality assurance department and the mobile workers in the workshop using smartwatches. Quality assurance test reports can be attached to give fast feedback. Acknowledgments of received notifications are advantageous: *“I visualize it to the quality assurance employee, and he knows in case that the worker is currently busy, but it is being done later”* (expert 1). In terms of statistics, *“it would also help us. Then you can find out what you can do better”* (expert 2). In this way, team leaders can obtain insights about their machines. Through eliminating ineffective steps, workflows can also be improved. This results in several economic advantages. *“I can decrease throughput times with it”* (expert 2) and hence, *“deliver reliability because I have less downtime and perhaps less waste, less time I produce”* (expert 4). Also, the employee benefits *“I do not want my employees to run through the workshop but to receive information directly”* (expert 2). This was neither possible with a ring nor traffic light systems because *“now you can transmit information”* (expert 1). *“The employee is more guided, which is exactly what I want”* (expert 4). And *“it is not so complex, it is easy to learn, especially for the young people who grew up with technical devices like that”* (expert 4).

The feedback also made us aware of some critical points. On a human level, there is a risk that *“an employee’s freedom is cut”* (expert 4). Equipped with a system that is able to assign tasks to a person, and *“there are few opportunities to disagree”* (expert 4), employees lose free decision about their acting. A corresponding question is *“who is allowed to assign tasks to whom at all”* (expert 4). In order to avoid conflicts at this level, it is very important that such a system is used as support and guidance and not abused to extract the maximal output of an employee. A crucial point is *“to discuss systems like this with the employees in advance, what are the reasons and benefits”* (expert 1) and *“we do not want put pressure on the employees”* (expert 1). According to the European GDPR, no personal data is collected and cannot be processed. *“It is not only data protection, but there are also practical reasons for this. We are interested in the machine and not in the person”* (expert 4). As well, it is not meant as a replacement for verbal exchange, so that *“the interpersonal communication falls by the wayside”* (expert 4). Alongside, organizational and technical properties are to be noted. *“There are a lot of different systems to be managed”* (expert 4) and *“the data maintenance must not be increased”* (expert 4), targeting complex interaction of many heterogeneous systems and redundant data storage in various formats. Another comment regarding the hardware is: *“I might have a problem with the size of the display, but I think it is a matter of habituation”* (expert 4).

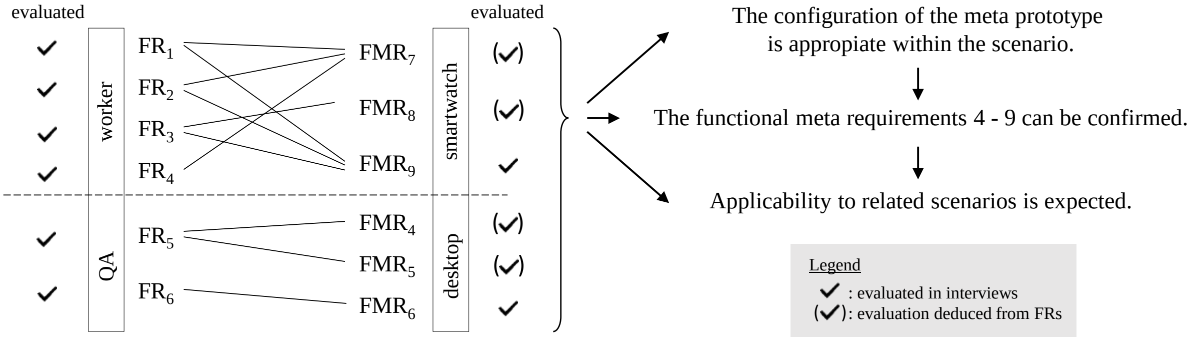


Figure 20. Relations of evaluated FRs and FMRs.

In summary, all experts found the presented prototype advantageous and deployable. *“I did not expect it to be so versatile at first”* (expert 4). So our software addresses the identified problems appropriately and offers many more possibilities for a company. *“I would even pay a lot of money for that because it is just important to be able to keep up with the competition”* (expert 2).

In Figure 20, we illustrate the relations of the FRs and FMRs. We have evaluated the functional requirements and showed that our prototype is appropriate within the given scenario. Since we can relate the deduced FMRs with the FMs, they can also be justified. Merely, FMR$_1$, FMR$_2$, and FMR$_3$ could not be directly confirmed because they do not arise from the scenario and the background of the experts. These are technical prerequisites for the other FMRs and originated from abstraction and formalization.

1.5 Discussion and Conclusion

In this paper, we presented a mobile information system introducing smartwatches for the support of employees in collaborative workflows within the industrial sector. Inspired by the design science research method of Peffers et al. (2007), we illustrated a strictly problem-orientated research design. We first identified and described the problem found in practice through a workshop series (RQ1). We formulated objectives and inferred requirements based on qualitative interviews with practitioners.

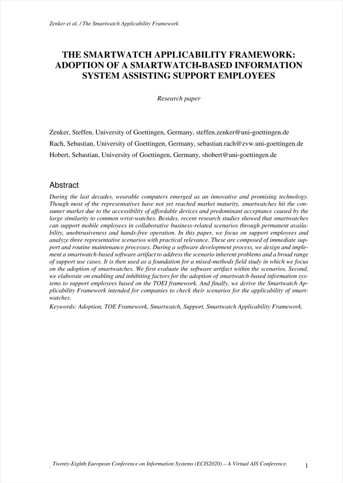
During the design phase, we developed functional meta requirements to address a broad range of similar problems. We presented the software meta-artifact *smartActivity* composed of a smartwatch application, a desktop backend, and a server infrastructure (RQ2). With this, it is possible to cover the original problem of supporting a workflow within a service system, including machine operators and a quality assurance division, where an exchange of information is slow, media distortions occur, and employees have a lot of unnecessary footpaths. In a demonstration step, we presented our system to practitioners and explained the applicability with a suited configuration and workflow. Subsequently, we gathered feedback during a workshop and qualitative interviews for an evaluation (RQ3). According to the experts, the unique features of *smartActivity* result in an improvement of the process and product quality as well as in a reduction of the employees' workload. Particularly, the rigorous collaborative workflow guidance based on uninterruptive, immediate, and location-independent information exchange was highlighted as a key feature and major contribution. Nevertheless, we also figured out some critical elements. It is very important that such a system is not to be used as a tool to put pressure on the employees or for surveillance but to offer support and guidance. In addition to the prototype, in practice, an authorization system for the desktop component is highly requested. It should be possible to assign different permissions to the levels in a company's hierarchy so that, for example, only a division leader can edit workflows. Another crucial factor is the deployed hardware. In the domain of smartwatches, handling is a big discussion due to the small display. Reducing the displayed information and interactive elements to the minimum necessary this limitation can be circumvented. Industrial environments make tough demands on smartwatches. Today's devices offer adequate battery life and are often water- and dust-resistant. But the wristband is prone to acids and the display can get inoperable contaminated, e.g., with oil. For many industrial cases, the manufacturers have to improve the durability of their devices to make them fully convenient.

As with any practice-oriented research study, some limitations exist: First, the empirical foundation of the developed meta-artifact is merely based on the quality assurance scenario. To address this limitation, we aim at transferring *smartActivity* to more use cases, though due to the paradigm of low-interaction, short-term and proactive use of smartwatches, there is a narrow field of application (Dvorak 2007). However, we verified the utility of smartwatches in a service system of a quality assurance scenario. According to the interviews, maintenance or support scenarios are promising. Employees who are widely dispersed over the company can at any time receive requests while using their hands for their proper work. Even non-collaborative workflows are possible, in which employees are just guided through a complex sequence of tasks, and they can make sure not to miss any step. To cover these new use cases, specific requirements have to be met. Second, our evaluation is limited as the participants of the evaluation could only test the application for a short time-frame. Hence, we want to conduct a long-term evaluation in the future to get detailed insights into the impact of smartwatches on the employees' work.

Nevertheless, for practice, we created an applicable software solution for many scenarios. We introduce new technologies to support employees in workflows. This helps companies to keep pace with the competition through the consolidation of employees. Within the research domain, we created a level 1 design science contribution (Gregor / Hevner 2013) in order to address the stated quality assurance scenario in practice. The presented meta-prototype forms the entrance to a level 2 contribution, identifying design guidelines by extension, application, and evaluation to more use cases. The accumulated insights and knowledge can help to understand how to integrate smartwatches into the industrial context and how to design mobile information systems based on smartwatches to support employees in workflows. For a proper level 2 design science contribution, including design principles, we need to traverse another design science cycle in order to generalize findings.

2 Support

The Smartwatch Applicability Framework: Adoption of a Smartwatch-based Information System Assisting Support Employees



Zenker et al. / The Smartwatch Applicability Framework

**THE SMARTWATCH APPLICABILITY FRAMEWORK:
ADOPTION OF A SMARTWATCH-BASED INFORMATION
SYSTEM ASSISTING SUPPORT EMPLOYEES**

Research paper

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Abstract

During the last decades, wearable computers emerged as an innovative and promising technology. Though most of the representatives have not yet reached market maturity, smartwatches hit the consumer market due to the accessibility of affordable devices and predominant acceptance caused by the large similarity to common wrist-watches. Besides, recent research studies showed that smartwatches can support mobile employees in collaborative business-related scenarios through permanent availability, unobtrusiveness and hands-free operation. In this paper, we focus on support employees and analyze three representative scenarios with practical relevance. These are composed of immediate support and routine maintenance processes. During a software development process, we design and implement a smartwatch-based software artifact to address the scenario inherent problems and a broad range of support use cases. It is then used as a foundation for a mixed-methods field study in which we focus on the adoption of smartwatches. We first evaluate the software artifact within the scenarios. Second, we elaborate on enabling and inhibiting factors for the adoption of smartwatch-based information systems to support employees based on the TOEI framework. And finally, we derive the Smartwatch Applicability Framework intended for companies to check their scenarios for the applicability of smartwatches.

Keywords: Adoption, TOE Framework, Smartwatch, Support, Smartwatch Applicability Framework.

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2.1 Introduction

During the last decades, wearable computers emerged as an innovative and promising technology due to their unique characteristics. The continuous increase in sales of wearable computers is currently significantly driven by smartwatches, which are forecasted to represent 64 % of total sales of wearables in 2022 (IDC 2018). One reason that smartwatches already hit the consumer market can be found in the public acceptance of these devices caused by the familiarity of common wristwatches and the experience of well-being while wearing them (Wu et al. 2016; Jung et al. 2016). In addition to that, the potential and utility of smartwatches for the corporate context was also emphasized in the last decade. Many dynamic processes necessitate high mobility, ubiquitous access to the digital workplace, and collaboration of employees. Especially, workflows, including manual work, disqualify the occupation of employees' hands with hand-held devices like smartphones or tablets (Kortuem et al. 1999; Billinghurst / Starner 1999). Smartwatches provide permanent availability, easy observation, unobtrusiveness, easy handling, and portability on the body, allowing almost hands-free operation, especially for receiving information (Ziegler et al. 2015) and hence met these requirements. They even can be used in a variety of demanding scenarios in which other hands-free devices like headsets reach their limit due to, e.g., high noise in production and the lack of reliable speech recognition for human-computer interaction.

Despite these potential benefits for enterprises, smartwatches are still rarely used by companies indicating low adoption and diffusion. One reason might be that smartwatches are frequently only seen as an accessory instead of a useful tool (Krey et al. 2016). Underlying influencing factors for the adoption of smartwatches in the corporate context might be important for researchers and managers to improve the understanding of which factors contribute to the adoption of this new technology. Getting a deeper understanding of the adoption can support the design and introduction processes of smartwatches in companies. Due to the promising utility of smartwatches, it is expected that smartwatches might have a beneficial impact to support employees by improving the efficiency of workflows. This can finally become an economic factor in terms of saving time and money (Ziegler et al. 2014). In previous studies and supported by many interviews with domain experts from the industry, especially the utility of smartwatches for support employees was emphasized (Zenker / Hobert 2019, study 1). Thus, we investigate support scenarios in this paper with the superordinate intend to assess influencing factors enabling and inhibiting the adoption of smartwatch-based IS in the corporate context. For that, we address the following three research questions:

> **RQ1:** How to utilize and adapt a smartwatch-based information system in IT support processes?

> **RQ2:** How do employees evaluate the artifact, and what are the enabling and inhibiting factors for an adoption?

RQ 3: How can companies evaluate corporate scenarios for the applicability of smartwatches?

To answer these research questions, the remainder of this article is structured as follows: First, we present definitions of basic terms and outline related research and practice in section 2.2. Second, we describe our research method, including a mixed-method approach in section 2.3. By applying the research framework to our problem domain, we illustrate the design and evaluation of our artifact in section 2.4. The focus of this work is the subsequent elaboration of enabling and inhibiting influences of the adoption of smartwatch-based IS within the support scenario inspired by the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014) in section 2.5. In section 2.6, we process our findings into the *Smartwatch Applicability Framework,* which can be used by companies to evaluate whether their scenarios and workflows can benefit from an application of smartwatches. Finally, we discuss our results and outline our research contributions for theory and practice in section 2.7.

2.2 Theoretical Foundation and Related Research

Smartwatches can be defined as a special form of mobile computers in the shape of digital wristwatches equipped with various sensors and wireless interfaces (Zenker / Hobert 2019, study 1; Cecchinato et al. 2018). They arose in the class of wearable computer devices during the last decades and are today the most prominent representatives. They can be delimited from other devices with a similar shape (like fitness tracker) by the characteristic that they are operated by a hardware-independent operating system, which can be extended by installable applications (McGrath et al. 2013). As all wearable computers, they are worn directly on the users' body and are therefore always available to the users, independently of a specific location or time (Boronowsky et al. 2008; Rhodes 1997). Due to the possibility to provide haptic feedback (e.g., vibrations) at the users' wrist, smartwatches can demand attention proactively, which is helpful to initiate interactions, e.g., when an important notification is received. Although smartwatches are technically similar to mobile devices, they are usually limited to simple input and output options due to the small form factor (Malu / Findlater 2015). Nevertheless, users can always interact with them since they wear devices on their bodies. In contrast, for using applications on mobile computers like smartphones, e.g., the Kanban-style task management tool Trello (Atlassian 2020), the device needs to get out of the pocket and to be held in a hand, which is not convenient for employees executing manual work but offers more advanced input and output capabilities (Chaparro et al. 2015). Research on wearable computers started more than 50 years ago (Thorp, 1998; Rhodes, 1997). Most research contributions target (1) technical aspects like sensor requirements for activity recognition (Bieber et al. 2013) or expanded input expressivity through mechanical interaction (Xiao et al. 2014) on smartwatches, (2) designing applications in private or business contexts such as a smart-glasses-based learning system (Hobert / Schumann 2017b) or a smartwatch-based system to support employees in collaborative industrial scenarios (Zenker / Hobert 2019, study 1), (3) the added value of wearable computers like studies about augmented reality-based information systems (Berkemeier et al. 2019), industrial deployment of wearable computer in the industry (Lukowicz et al. 2007), or the use of wearable and augmented reality technology in industrial maintenance work (Aromaa et al. 2016) as well as (4) usability aspects regarding smartwatch applications like the Wear OS *usabilityWatch* framework (Zenker / Hobert 2020, study 6). Some companies presented several smartwatch-based products such as *MeisterTask* (MeisterLabs GmbH 2020)*, Hipaax TaskWatch* (Hipaax LLC 2020)*, aucobo (aucobo GmbH 2020),* and *WORKERBASE* (WORKERBASE GmbH 2020). However, available products, to the best of our knowledge, have a limited range of functionality, do not provide any scientific background, or are not eligible for scientific studies, since the source code cannot be accessed.

As smartwatches are not widespread in enterprises yet, we investigate influencing factors for adoption. This term refers to the acceptance, integration, and use of innovative technology like smartwatches in society. It determines the diffusion of technology. There are many theories about technology adoption in IS research (Oliveira / Martins 2011). The most prominent models concerning the corporate level are diffusion of innovation (DOI) (Rogers 1995) and the technology, organization, and environment (TOE) framework (DePietro et al. 1990), which then was extended to TOEI complementing individual factors (Rosli et al. 2012; Hoong / Marthandan 2014). Especially, TOE is used to assess technology adoption in a broad range of fields. For instance, Lippert / Govindarajulu (2006) utilized it for web services, Demertzoglou (2007) for open source databases, Borgman et al. (2013) for cloud computing, and Chiu et al. (2017) for broadband mobile applications. In addition, there are frequently used models like the technology acceptance model (TAM) (Davis et al. 1989), theory of planned behavior (TPB) (Ajzen 1985), the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al. 2003), but they apply only at the individual level. Underlying inhibitors and enablers can be seen as a dual-factor concept in technology usage (Cenfetelli 2004) and the user perceptions according to information technology innovations have to be measured with an adequate instrument (Moore / Benbasat 1991). The adoption and diffusion of smartwatches in the corporate context remains still largely unexplored. Nevertheless, there are first efforts like determinants for adoption in the medicinal domain (Su / Gururajan 2010), influencing factors and challenges in the industrial sector (Hobert / Schumann 2017a), or student influencing factors (Adapa et al. 2018) of the adoption of wearable computers in the consumer and corporate context. Furthermore, Page (2015) gives a forecast of the adoption of wearable technology. Regarding smartwatches, there are predominantly studies within the consumer context. Dehghani (2016), for example, analyzed the adoption and diffusion of smart wearable technologies like smartwatches and fitness wristbands by consumers. Cho / Park (2016) examined the diffusion of smartwatches in the Korean consumer market. The role of usefulness and visibility in smartwatch adoption was amplified by Chuah et al. (2016). Kim / Shin (2015) developed an acceptance model for smartwatches. Besides, device characteristics were in focus. Kim (2016) investigated whether screen shapes like round and squared affect the adoption of smartwatches. Hsiao (2017) identified adoption intention while comparing Apple and non-Apple smartwatches. Choi / Kim (2016) survey factors affecting the intention to use smartwatches as an IT product or a fashion product. However, research on the adoption of smartwatches in the corporate context remains limited.

2.3 Research Design

To analyze smartwatch adoption and to derive the *Smartwatch Applicability Framework* as outlined in section 2.6, we apply a threefold mixed-methods approach (see Figure 14). First, we design a software-artifact traversing a process inspired by the design science research model of Peffers et al. (2007). Second, we utilized the software as an instrument to elaborate on enabling and inhibiting factors for smartwatch adoption considering the four categories introduced by the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014) based on interviews regarding a field study. Finally, we construct the *Smartwatch Applicability Framework* as the main contribution of this paper.

According to our design process, the design of the artifact should be grounded in the problem identification phase (step 1). For that, we rely on the results of a series of workshops that we conducted in summer 2017 within industrial production facilities. The main goal of these workshops was to identify application scenarios for wearable computers, which are beneficial for companies and employees. Besides, we conducted further focus interviews from November 2017 to August 2019 regarding smartwatches in the corporate context with technicians, team leaders, and managers. This includes employees of two large-scale biotechnology companies, several medium-sized companies within industrial production, and a large-scale university IT department with approximately 700 employees at over 40 different locations. A predominantly mentioned application for smartwatches was the domain of support and maintenance (see section 2.4.1), which then became the focus of this work.

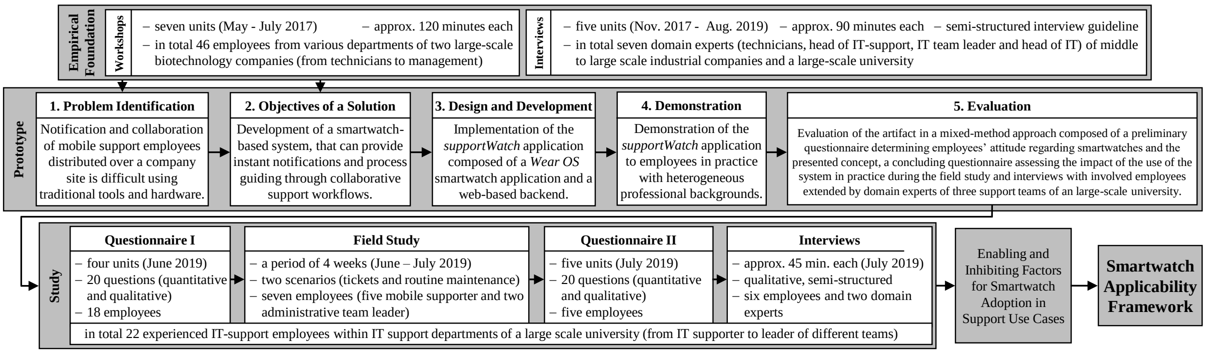


Figure 21. Research design with the respective empirical foundation

Based on this scenario, as the identified real-world problem, we derive functional requirements as the objectives of our solution (step 2). For this purpose, we carefully analyze the documentation of the workshop series and interviews. During these studies, the involved employees explained in detail how their current workflows are designed and how they believe that smartwatches can assist them during their daily work. Overall, we acquire four requirements that are the basis for the subsequent design cycle.

Following the design process, we create the *supportWatch* application based on the deduced requirements (step 3). We build our research on an existing software meta-artifact providing a smartwatch-based IS suited for a broad range of use cases (Zenker / Hobert 2019, study 1). With respect to Iivari (2015), we utilize his strategy one to instantiate the general concept of the meta-artifact into a specific solution to adapt it to our specific support context solving the identified problems in practice. During this process, new functionalities are added to the artifact. By choosing an agile development approach, we can discuss intermediate prototypes regularly, and we involve a team leader of the IT-support department within a large-scale university in the development process to improve the software constantly until it met all requirements. However, the focus of this work is to investigate the adoption of smartwatch-based IS in the corporate context, and we utilize the prototype as a tool to access related influencing factors.

Subsequently, we conduct a demonstration according to the research design in step 4. For this, we demonstrate *supportWatch* during four live presentations (each approx. 60 minutes) involving volunteering employees of different teams in the IT department of a large-scale university working in support scenarios. This includes 22 employees working in the teams of student IT-infrastructure support, lecture hall technology support, and electronic assessment support. Most of the employees have several years of experience in their support job. Also, the four team leaders attend the presentations.

Building on that, we enter an evaluation phase (step 5). Subsequently to the demonstration sessions, the participants are asked to fill in a quantitative and qualitative questionnaire with 20 questions to evaluate their attitude regarding smartwatches and their rating of our concept. In this way, we have collected 18 reasonably completed questionnaires. After that, we started a field study for two of the scenarios, including tickets and routine maintenance (see section 2.4.1). Five employees were equipped with smartwatches and used the system for over one month in their daily work (two additional team leaders were involved as supervisors using the web-based component at their desktop environment). To conclude the study, we performed a second round of the questionnaire with the five employees who have used the smartwatches during the field study and conducted qualitative semi-structured interviews with all eight participants, including the three team leaders. The interviews took approx. 45 minutes each, and the participants are asked about their attitude and experience using the smartwatch-based IS during their daily work.

Finally, we analyze the findings of the interviews by coding and categorize enabling and inhibiting factors influencing the adaption of smartwatch-based IS. We systematize the factors according to four categories as proposed by the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014). Finally, we used the identified categories as the starting point for deriving the *Smartwatch Applicability*

Framework. To demonstrate the applicability, simplicity, and usefulness of the framework, we exert it to the three support related scenarios and an additional scenario from industrial production.

2.4 Design of the *supportWatch* Application

In this section, we present the design of the *supportWatch* application assisting workflows of support employees with smartwatches. This results in a software solution that can be applied in practice.

2.4.1 Problem Identification

During a workshop series targeting the capabilities of wearable computers in the industrial context and interviews with domain experts, a similar request appeared in the different kinds of companies: to utilize smartwatches for support employees. This is very promising, since supporters, ranging from technicians fixing machine outages to IT-supporters handling soft- and hardware problems, usually are mobile covering the entire company site, have to work collaboratively with their colleagues reconciling task assignments and have to react quickly to incidents requiring a noticeable notification while executing manual work. For this paper, during the discussion with the persons in charge, we identified three support scenarios predominantly characterized by many human-to-human interactions of a large-scale university illustrated in Figure 22, building the foundation of investigations in this paper.

Scenario (A) is grounded in the student IT-infrastructure support team. The employees have three primary areas of responsibility concerning public desktop workplaces, computer pools, and printers for students. First, they give support for soft- and hardware-problems, and second, they have to perform scheduled site inspections. Students can submit tickets in case they have technical issues at their workplace. These tickets accrue in a queue and are assigned to the support employees by the team leader at a desktop system, automatically or by the employees themselves. Also, the dispatcher allocates site inspections in which, e.g., every PC in a pool is investigated and checked for proper functionality. The concerned mobile supporter then has to complete these tasks as fast as possible with a priority on the tickets and has to give feedback about the results (e.g., whether a defect occurred and is repaired).

A similar scenario (B) is rooted in the lecture hall technology team. Lecturers use various digital systems as smartboards, projectors, microphones, cameras, and PC systems, including a broad range of software, during their lectures. Whenever technical problems occur in a lecture hall, lecturers need to contact the support by telephone, by (e-mail) ticket, or orally. The responsible team leader gathers all requests and transfers the tasks to the system. In the case of multimedia device defects, the ticket is passed to another team having specialized technicians. Based on the priority, requests have to be solved by mobile employees. If there is, for instance, a failure with the presentation PC and the lecture cannot continue, this has to be addressed immediately. Other issues like a request to install new software for future lectures has lower priority. Besides periodic routine maintenance according to a checklist is executed (e.g., hardware checks and software updates). Every time feedback is required, whether problems occurred, which necessitate additional knowledge and effort to solve them efficiently.

Finally, scenario (C) applies to technical support in electronic assessments. Within the context of written examinations, students solve questions at individual PC workplaces in computer pools. Frequently the amount of students requires to use multiple rooms, which have to be coordinated (e.g., for a start and stop signal) by the responsible lecturer. Since PCs can drop out, or the periphery is not working correctly, in each room are technical support employees, who can solve these problems instantly during the examination without any time disadvantage for the student. Besides, a technical supervisor manages technical issues in real-time. This requires direct and silent communication between the employees to ensure adequate reactions within this critical period.

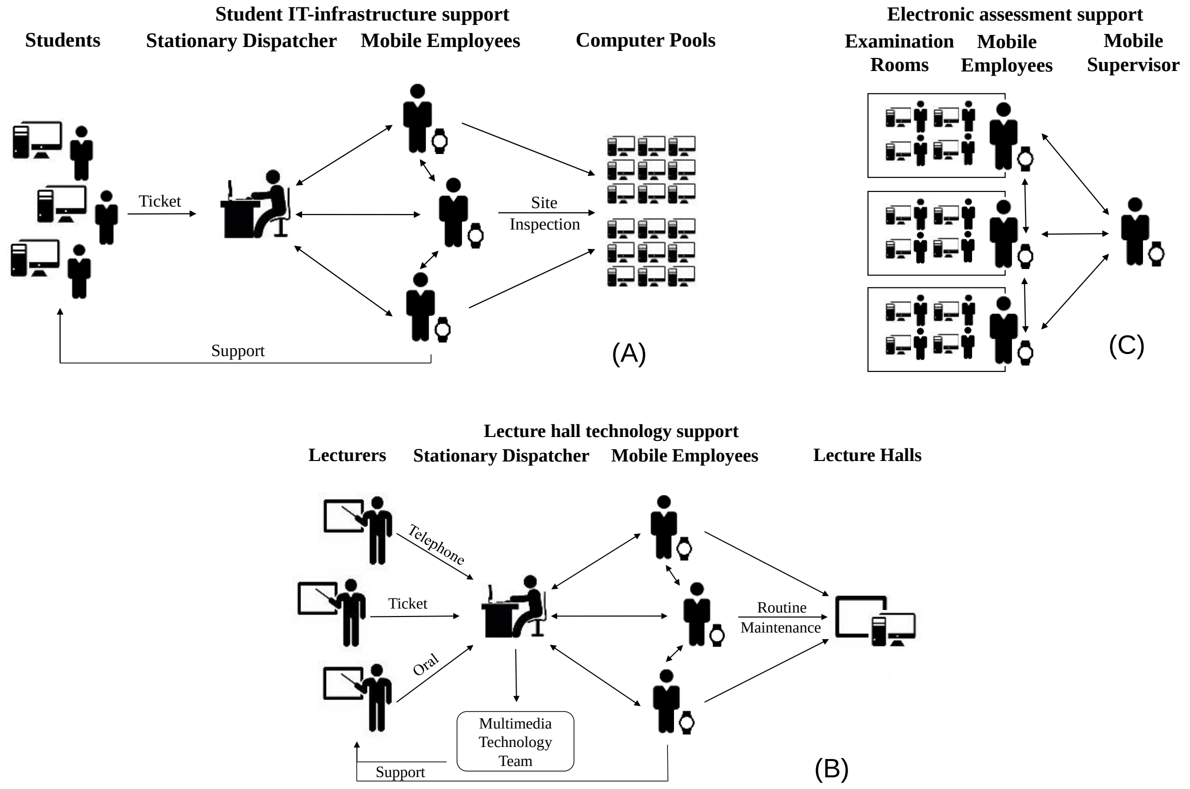


Figure 22. Three university support scenarios

These workflows offer the potential for improvement through digitalization due to two key problems. On the one hand, collaboration is complex due to employees are spread over the university, impeding oral agreements, fast and efficient reactions to technical incidents are difficult, and recent mobile communication systems require both hands for operation and interrupt manual work. On the other hand, there are media disruptions, including digital, auditive, printed, and written representations of information sharing and personal notes.

2.4.2 Objectives

While analyzing and discussing the previously described scenarios with the team leaders, we can identify two main scopes we have to address in the smartwatch-based IS:

1. Tickets arrived in the existing queues should be transferred to *supportWatch*, assigned to an employee, who is then able to process the task assisted to the smartwatch.
2. We have to provide a possibility to manage scheduled site inspections with corresponding tasks that can be automatically assigned to employees who then can process their tasks successively.

To achieve this, we need to provide an interface for the ticket systems of the university for bidirectional information exchange, transferring tickets, and returning results of the processing (FR_1). Furthermore, dedicated tasks have to be automatically generated and assigned to the employees' smartwatches (FR_2). For the handling of tickets, employees should be guided through the workflow, and there should be reasonable, predefined options to conclude tickets arranged in categories (FR_3). To provide support for site inspections, the management of sites, and an organization of scheduled inspections due to maturity are required (FR_4).

We summarize all functional requirements for *supportWatch* in Table 9, complementing the scope of operation of the underlying meta-artifact, which then builds the foundation for the design and implementation of the new functionalities in *supportWatch* presented in the next section.

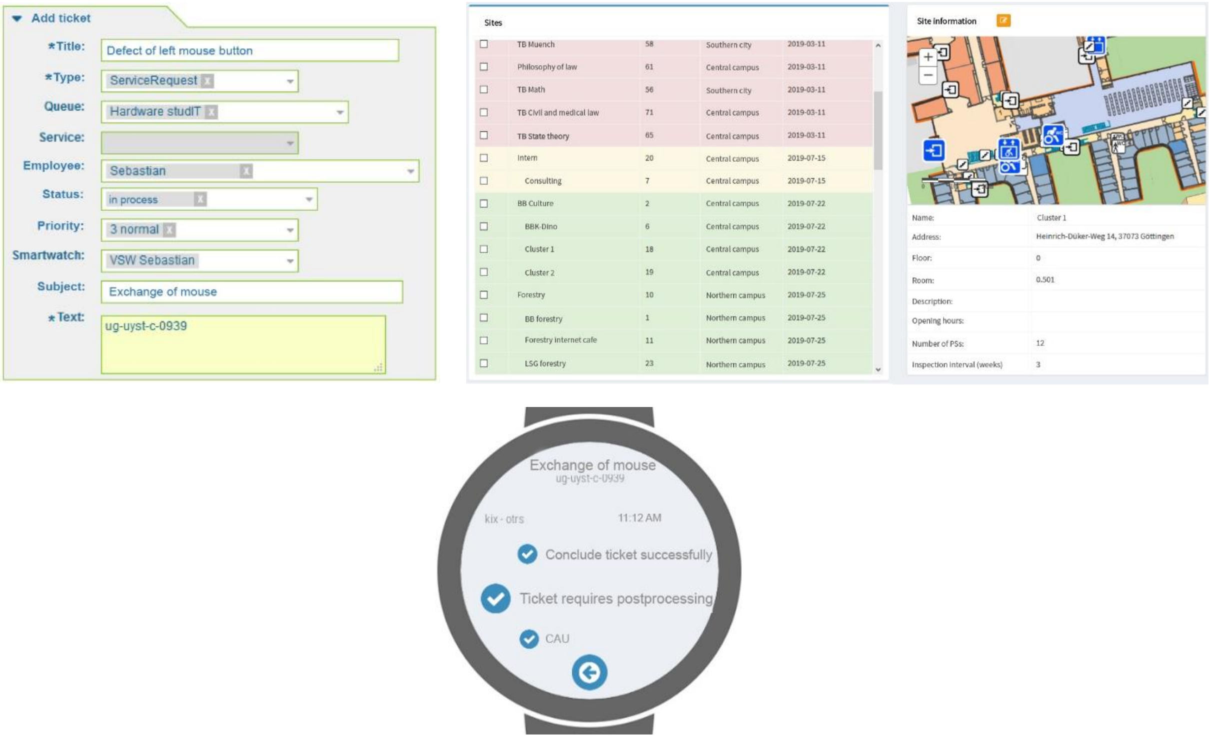
Requirement		**Description**
FR_1	Interfaces for paired systems	interface to ticket systems, for the input of tickets and to return the processed ticket result
FR_2	Generation of assignments	tickets and site inspections have to be assigned as tasks to employees' smartwatches
FR_3	Ticket handling	process guidance with reasonable options to conclude a ticket
FR_4	Site inspection handling	management of sites, organization of site inspections due to maturities

Table 9. Functional requirements for *supportWatch*

2.4.3 Design and Development

As we can rely on an existing meta-artifact developed by Zenker / Hobert (2019, study 1), the system already provides a web-based desktop backend and a *Wear OS* smartwatch application. This includes all functionalities for the basic interaction between the smartwatch and the web-backend users, a REST-API, workflows enabling process guidance, assignment of activities, and workplace management. During the conception and implementation phase, we deeply involved the leader of the student IT-infrastructure support team. In this way, we productively can apply the changes and modifications for the adoption to fit the requirements of support employees.

In the following, we present the implementation of the ticket workflow. First, a ticket occurs at the university ticket system. There are multiple frontends in which students, lecturers, or employees can add tickets (see Figure 23 (left)). We modified the corresponding system that it calls the *supportWatch* API whenever a scenario related ticket is submitted into the queue (FR_1). Second, *supportWatch* creates a new activity with the team leader as the responsible person (FR_2). According to the workflow, the ticket can now be dispatched to a mobile employee. Then, the request appears at the employees' smartwatch (see Figure 23 (right)), the ticket can be processed, and the corresponding action can be selected, e.g., the PC has to be replaced (FR_3). Finally, according to the selection, the result is returned to the ticket system over another interface, and a respective status is stored (FR_1).



*Title: Defect of left mouse button
*Type: ServiceRequest
Queue: Hardware studIT
Service:
Employee: Sebastian
Status: in process
Priority: 3 normal
Smartwatch: VSW Sebastian
Subject: Exchange of mouse
*Text: ug-uyst-c-0939

Sites

☐	TB Muench	58	Southern city	2019-03-11
☐	Philosophy of law	61	Central campus	2019-03-11
☐	TB Math	56	Southern city	2019-03-11
☐	TB Civil and medical law	71	Central campus	2019-03-11
☐	TB State theory	65	Central campus	2019-03-11
☐	Intern	20	Central campus	2019-07-15
☐	Consulting	7	Central campus	2019-07-15
☐	BB Culture	2	Central campus	2019-07-22
☐	BBK-Dino	6	Central campus	2019-07-22
☐	Cluster 1	18	Central campus	2019-07-22
☐	Cluster 2	19	Central campus	2019-07-22
☐	Forestry	10	Northern campus	2019-07-25
☐	BB forestry	1	Northern campus	2019-07-25
☐	Forestry internet cafe	11	Northern campus	2019-07-25
☐	LSG forestry	23	Northern campus	2019-07-25

Site information

Name:	Cluster 1
Address:	Heinrich-Düker-Weg 14, 37073 Göttingen
Floor:	0
Room:	0.501
Description:	
Opening hours:	
Number of PSs:	12
Inspection interval (weeks)	3

Exchange of mouse
ug-uyst-c-0939
kix - otrs 11:12 AM
Conclude ticket successfully
Ticket requires postprocessing
CAU

Figure 23. The components of *supportWatch*: (left) ticket system, (middle) overview over sites with color-indicated maturity including a map and (right) smartwatch view of the ticket and corresponding options

For site inspections, we added a new tab to *supportWatch* in which sites can be managed (see Figure 23 (middle)), and an import of rooms with a list of the IT-equipment over a university API is available (FR_1). Hence sites hold information about the location, a map, and the maturity of the inspection indicated by color, e.g., red are the most urgent ones (FR_4). Whenever an inspection is due, the system automatically generates activities for each site (FR_2). According to the created workflow, these activities can be assigned to mobile employees who process the inspections guided by their smartwatch. Finally, the site inspection is concluded with a respective status that is stored by the system, and possible next steps can be triggered.

2.4.4 Demonstration

To initially introduce support employees within the university scenarios to smartwatches and the *supportWatch* application, we conduct a demonstration according to our research process. For this, we organized several live presentations involving the different teams and first presented basic information and the potential of smartwatches and second the *supportWatch* application within a realistic scenario. This includes 22 employees working in the previously defined scenarios and accordingly for the teams of student IT-infrastructure support, lecture hall technology support, and electronic assessment support. In addition, the four team leaders attend the demonstrations. All participants were rather open-minded and interested in our ideas as well as in smartwatches as an innovative device. To obtain deeper insights into the impression of support employees and impacts to support workflows regarding our system, we conducted a field study within two of the scenarios. Accordingly, *supportWatch* was integrated into these scenarios over four weeks, five employees are equipped with smartwatches, and two team leaders used the web-based backend.

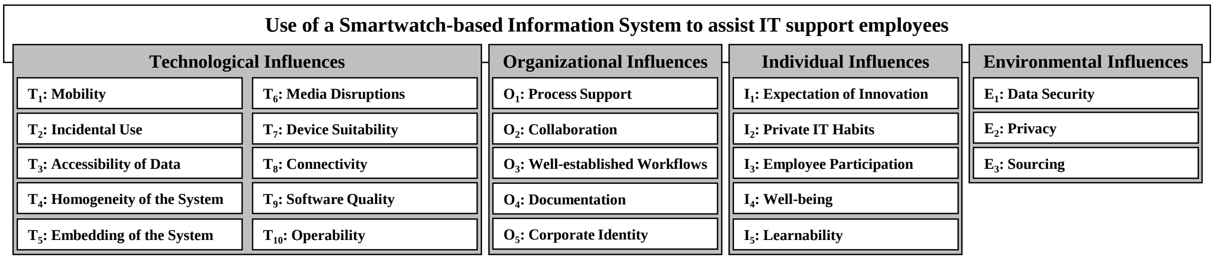
2.4.5 Evaluation

Subsequently to the demonstration, we first conducted a questionnaire study to evaluate employees' attitudes concerning smartwatches and their ratings about the concept. We determined that just 16 % of the participating employees have recently used smartwatches in private, and none of them in the corporate context. Nevertheless, some participants consider purchasing a smartwatch caused by the study due they like the functionalities such as *"a fast overview, notifications and that it is always at the body"* (Q_1-Exp15) and *"heart rate measure and direct vibrations at my wrist"* (Q_1-Exp17). The survey shows that 34 % of the participants found the idea to use smartwatches in the corporate context very good, 44 % assigned to good, 22 % to okay, and nobody to bad or very bad. Overall 62 % indicated that they do not have doubts about using smartwatches at work and that smartwatches *"can accelerate workflows and make communication easier"* (Q_1-Exp11) and *"provide fast reachability in case of critical tasks"* (Q_1-Exp15). On the opposite side, 38 % remarked concerns like *"protection of personal data,* *tracking, low battery capacity, and small display size"* (Q_1-Exp18). On a scale ranging from 1 (very bad) to 7 (very good), the participants evaluated the idea to assist their work with a smartwatch-based system with 5.8 on average. In detail, they rated 6.0 for the case of site inspections, 5.6 for processing tickets, and a 5.7 to use the presented system during their work. The utility of functions regarding the site management got a 6.1 and the ticket system a 5.9.

Questionnaire 2, which was conducted subsequently to the field study, shows that the employees are even more convinced of the idea to use smartwatches in their daily work after they had the chance to practically apply and test the system raising the approval to 80 %. They positively evaluated *supportWatch* but emphasized several issues that have to be improved in the prototype to ensure practicability. Amongst others, sometimes crashes occurred, connection establishment took unreasonably long, and the usability of the application can further be revised. Although the study increased the consent for smartwatches in the corporate context, the study tightened concerns as *"the smartwatch assists my daily work, but I also feel more supervised"* (Q_2-Exp5).

2.5 Adoption of a Smartwatch-based Information System

In this section, we present the results of the evaluation of the *supportWatch* application with a focus on the adoption of *supportWatch*. We carefully analyze the answers of the participants of the field study in the interviews and extract enabling and inhibiting factors for the application of smartwatches within the considered scenarios by a coding procedure. Inspired by the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014), we categorize these influences into technological, organizational, environmental, and individual, as illustrated in Figure 24.



Use of a Smartwatch-based Information System to assist IT support employees

Technological Influences		Organizational Influences	Individual Influences	Environmental Influences
T_1: Mobility	T_6: Media Disruptions	O_1: Process Support	I_1: Expectation of Innovation	E_1: Data Security
T_2: Incidental Use	T_7: Device Suitability	O_2: Collaboration	I_2: Private IT Habits	E_2: Privacy
T_3: Accessibility of Data	T_8: Connectivity	O_3: Well-established Workflows	I_3: Employee Participation	E_3: Sourcing
T_4: Homogeneity of the System	T_9: Software Quality	O_4: Documentation	I_4: Well-being	
T_5: Embedding of the System	T_{10}: Operability	O_5: Corporate Identity	I_5: Learnability	

Figure 24. Enabling and inhibiting influences of the adoption of smartwatch-based IS to support employees inspired by the TOEI Framework

First, we examine technical aspects, starting with the major characteristics of smartwatches. For experts, **mobility** (T_1) is uniquely advantageous. *"This is the possibility to automate mobile processes through digitalization using such a small computer that you carry around on your wrist"* (I-Exp1). Concerning site inspections, one participant stated: *"it is exhausting to go to 165 locations that we care of, put out your laptop, write things down and inform the colleagues"* (I-Exp6), implying that mobility is limited with recently used devices. Nevertheless, smartwatches can lead to unnecessary effort in which other devices are superior: *“the employees stay in a room to supervise the exams and have a desktop computer at their disposal”* (I-Exp8) showing, that mobility is not required in every scenario. The **incidental use** (T_2) is described as *“I liked that you wear something on your body that you can’t forget or lose and you always have your hands free”* (I-Exp8). It turned out to be useful that *“I was able to take data incidentally into the system while going to the next location”* (I-Exp3), and thus *“this is a big time gain”* (I-Exp2). During manual work, *“there’s an advantage because when I disassemble a PC, I usually have to put a mobile phone out of my hand”* (I-Exp3) *“and so I can check the watch on the side and see what I have to do”* (I-Exp2). Smartwatches make it possible to provide **accessibility of data** (T_3). *“I extremely liked the fact that you have an up-to-date overview on one screen indicating locations to be checked and who the contact persons are”* (I-Exp5). Another topic is the **homogeneity of the system** (T_4). *“The possibility to have a web interface where I can work reasonably on the computer, to have a smartwatch app that is coordinated with it and work together with the other systems – that’s what I liked about it”* (I-Exp3). *“Before you had e-mails all the time”* (I-Exp6), *“and now you have all this bundled in one app”* (I-Exp3). Furthermore, the **embedding of the system** (T_5) is an influence as it is disruptive if systems do not work together and employees even have to substitute an interface in terms of *“I was the interface in person and had to copy and paste everything from the one to the other system”* (I-Exp6). To circumvent deficits sometimes *“we have used a public instant messenger even beyond our team for missing communication functionality”* (E-Exp1). *“In the ideal case, I can order spare parts directly within the system”* (I-Exp4). **Media disruptions** (T_6) make workflows inefficient and error-prone. *“An employee of the multimedia technology team first made a note concerning a ticket, then texted me using an instant messenger, and I forwarded it by telephone to the fault message center and returned feedback. Such circles are not effective for us”* (I-Exp6). Next, experts considered device- and software-related aspects. The **device suitability** (T_7), on the one hand, includes the battery life, which *“was at 50 % after a two-hour site inspection - the watch couldn’t last a real working day without charging”* (I-Exp5). *“A smartwatch should at least last one shift otherwise there is a huge time loss since charging is impractical”* (I-Exp6). On the other hand, it is required that the device is robust to physical and chemical stress as *“the smartwatch has to endure the impact of an accidental collision or wet weather”* (I-Exp1). A prerequisite is good **connectivity** (T_8) which *“must be guaranteed”* (I-Exp8), but *“many smartwatches do not support enterprise wireless protocols with custom certificates”* (I-Exp7). Since *“there are always locations where the signal is not sufficient”* (I-Exp4) *“it would be helpful to equip the smartwatch with a SIM card”* (I-Exp4). Because programming smartwatch applications is a new field, bad **software quality** (T_9) may lead to *“multiple software crashes”* (I-Exp5) or situations where *“the smartwatch overheats and turns off after a few minutes”* (I-Exp1). For daily work, **operability** (T_{10}) is an important factor. *“First I was worried that it might be difficult to operate and tap on the smartwatch since the display is small, but it works relatively well”* (I-Exp1) in case of *“control elements were appropriately dimensioned, and I didn’t have to enter any letters or numbers”* (I-Exp5). Nevertheless, *“for complex or variable events the predefined options are very restrictive and text input would be great”* (I-Exp8).

Second, there are organizational influences since smartwatches may have an impact on workflows. A promising characteristic of smartwatches is **process support** (O_1), which *"has already structured my way of working more effectively and I don't have to keep so many things in mind cause the system assists me"* (I-Exp2). *"The traffic light system is great since this guides me according to priorities"* (I-Exp4). Situations of working in teams can benefit from **collaboration** (O_2). *"You know you're taking a task and you are responsible for the ticket now"* (I-Exp2) and *"it is possible to hand over a ticket to a colleague when I couldn't process it at a day anymore"* (I-Exp2). A way to support collaboration is to enable transparency of processes. *"My principal can see the progress of my work and assign new tasks to me every time"* (I-Exp1), and *"feedback about actual processes is beneficial for the other employees in our team as well"* (I-Exp6). Smartwatches allow a fast flow of information and response, in terms of *"quickly inform people, what we're doing about instant messenger right now"* (I-Exp6). *"I get instant notifications on the smartwatch and then can react directly to tasks"* (I-Exp5). *"If you get messages on your smartphone and don't look at it, this can lead to difficulties - then it makes sense if a device on your wrist lights up and vibrates"* (I-Exp8). **Well-established workflows** (O_3) and habits can limit empathy for new developments. *"Because I'm also used to work with the current process, there was also the worry, if we have to change everything or we can adjust it somehow"* (I-Exp6). To make work more comprehensively, workflows can benefit from **documentation** (O_4). *"If there is an issue and the same happens again, we can assert that the problem still exists and apply the same solution again"* (I-Exp6). Ultimately, *"we can track the frequency of events and use them for process improvements"* (I-Exp7). As a last idea, **corporate identity** (O_5) was discussed by the experts. *"Smartwatches have a recognition value"* (I-Exp4), and *"employees should be recognizable to radiate professionalism"* (I-Exp7).

Third, individual influences are taken into account. Employees have some **expectations of innovation** (I_1) based on their private use of technology. *"At home, people are completely digital and use the smartphone, and at work, they are suddenly supposed to use pen and paper"* (I-Exp8). *"I would like to hear more » wow, that's cool! « in the business context"* (I-Exp6). Furthermore, employees have different **private IT habits** (I_2) and experiences that companies have to handle. *"Some of my employees even cannot operate their smartphone – smartwatches are even more difficult"* (I-Exp7). *"There are big differences in the operating system – in private, I have an Apple Watch and an iPhone, and I think it is qualitatively not comparable"* (I-Exp3). For body-connected devices, it is important to allow adequate **employee participation** (I_3) during the introduction of smartwatches. *"I would like to wear them beforehand and influence the watch strap"* (I-Exp5). Other experts discussed besides *"we should have individual smartwatches, which are issued and returned after the shift"* (I-Exp7) a company smartwatch or a bring your own device model. Strongly connected is the **well-being** (I_4) of employees. *"I have a problem wearing wristwatches - it is just terrible for me, I get anxiety feeling, and a plastic strap is just an additional factor"* (I-Exp5). To get employees quickly used to a new system, **learnability** (I_5) is a crucial factor. *"It is important that it is as simple and self-descriptive"* (I-Exp8). *"First, I had to concentrate a lot on the operation of the smartwatch, but after a little, I get used to it"* (I-Exp2).

Finally, there are environmental influences. **Data security** (E_1) is important for companies to store and transmit valuable data. *"If a watch gets lost - especially outside the company premises, the data should not be directly readable, and password protection would also be good"* (I-Exp7). *"I want our data to remain in our network and be encrypted. Use the mobile network only if necessary"* (I-Exp7). Also, private data should be secured, and *"for me, a strict separation of professional and private data is necessary"* (I-Exp5). A crucial concern for many employees is **privacy** (E_2), indicating fear of the abuse of personal data and surveillance. *"You have to deliberate which personal data you are allowed to collect and what purpose this makes. This must be negotiated with the works council"* (I-Exp7). There are neutral valuations like *"I don't know if it would change the way I work, but it would keep me thinking about"* (I-Exp3). More dismissive ones like *"in principle no, because it is a technical device that is connected to my body that is over the top for me"* (I-Exp5) and *"this fusion of internet and body, creates a feeling of insecurity for me"* (I-Exp5). Others stated: *"I'm being watched 24 hours a day from whatever institutions via my mobile phone anyway - I don't care about that at all"* (I-Exp1). In many companies **sourcing** (E_3) is a decisive factor since *"money is always rare in the corporate context"* (I-Exp8).

2.6 Smartwatch Applicability Framework

Founded on the findings in section 2.5 and the previous studies, we wrap up the enabling, and inhibiting factors for the adoption of smartwatch-based IS and develop the *Smartwatch Applicability Framework* as a final contribution of this paper. This framework is designed to guide companies that consider using smartwatches to assist their employees during daily workflows, e.g., in the support domain as motivated in this work. For this purpose, we have divided the influencing factors into two groups: (1) factors that are relevant to evaluate an existing scenario for the applicability of smartwatches and (2) factors that have to be considered when introducing a smartwatch-based IS at a company.

The framework (as illustrated in Figure 25) is composed of eleven statements (S_1-S_{11}), which are successively evaluated from top to bottom. For each statement, the targeted scenario of the company is analyzed, and it is checked whether the statement is *appropriate*, *partially appropriate,* or *not appropriate*. For a proper proposition, it is important to assess the scenario from a holistic and idealized view to recognize potentials and not just to focus on the actual state of it.

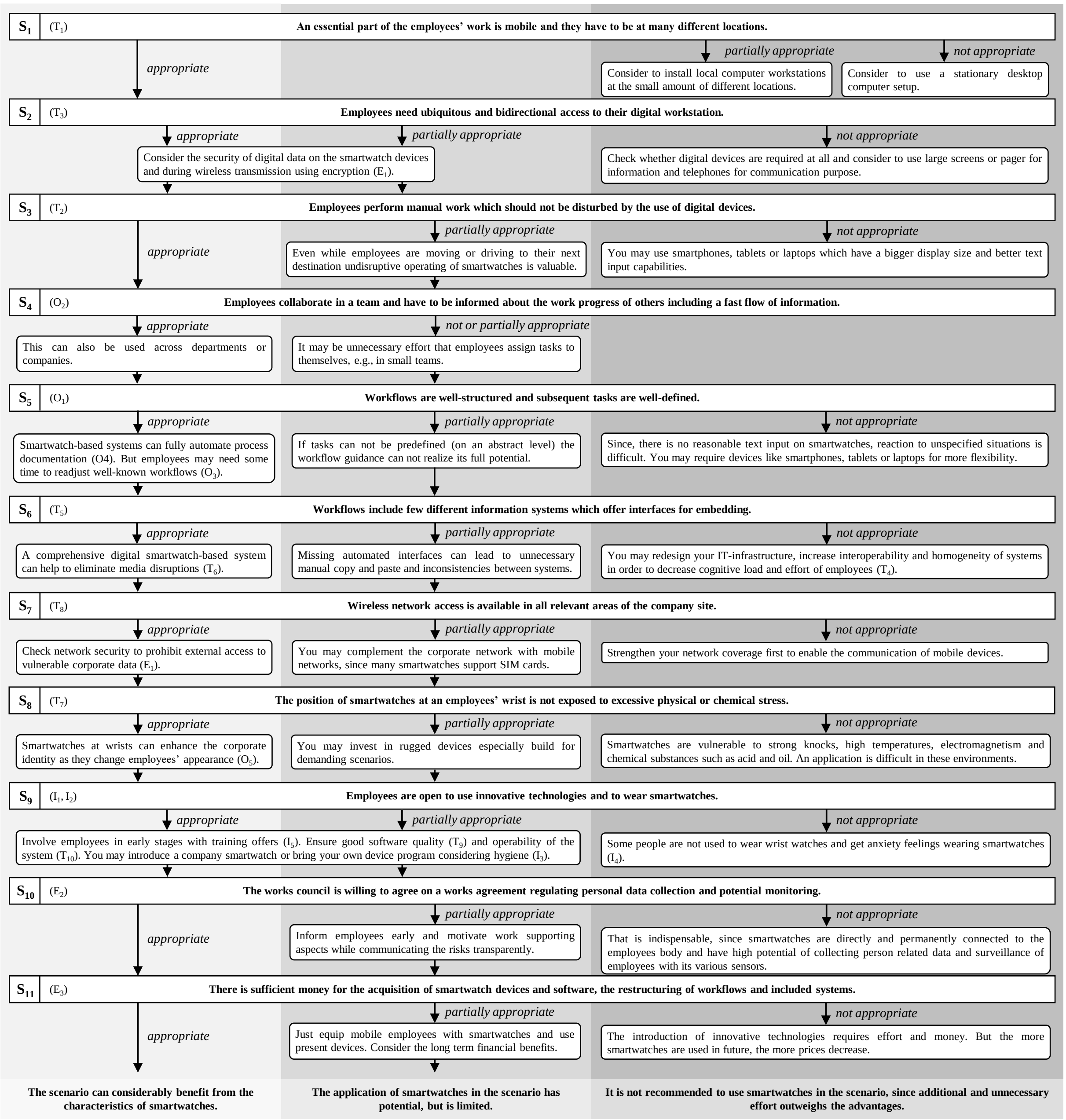


Figure 25. The Smartwatch Applicability Framework

As noted in Figure 25, the statements are directly deduced from the influencing factors (see Figure 24), are to some extent combined, enriched with some details, and edited in such a way that they become easily understandable and evaluable for practitioners. We ordered the statements by importance implicated during the interviews starting with the main characteristics of smartwatches and ending with several environmental influences. Whenever a statement is assessed, the framework provides recommended actions, respectively. These are arranged in three lanes which are correlated to the final recommended decisions: (right) it is not recommended to use smartwatches since additional and unnecessary effort outweighs the advantages, (middle) the application of smartwatches has potential but is limited, and (left) the scenario can considerably benefit from the characteristics of smartwatches. In case an evaluation results in the right lane, the process of decision finding concludes immediately. Besides, the framework explains why the according conditions disqualify a smartwatch-based IS for the given scenario and provides advice for a solution. If an evaluation results in the middle or left lane, the framework provides details regarding possible limitations and hints which aspects should also be considered respectively. In both cases, the process continues with the next statement and concludes past S_{11} with the lane inherent result. During the hole decision finding, lanes can be switched to the right at every statement but not to the left, e.g., when the middle lane is reached, and the next statement is evaluated with *appropriate,* the middle lane is kept until the end (or the right lane is entered) since some limiting factors are found previously. All advice is elaborated during the interviews or is an implication from the already conducted studies in practice with prototypes (Zenker / Hobert 2019, study 1; Zenker / Hobert 2020, study 6). They are either introduced as conceptual ideas or stated in the discussions regarding the limited success in a part of the scenarios (cf. section 2.4.1) by the involved experts.

To demonstrate the applicability, simplicity, and usefulness of the framework, we apply it to the scenarios presented in section 2.4.1 and summarize the results in Table 10. Since scenarios (A) and (B) share some similarities, we examine them together. For both $S_1 – S_3$ are *applicable*, due mobile employees are working at potentially every university facility spread over the city, who require to exchange information predominantly for collaboration and executing manual tasks. However, S_4 for both is *partially applicable* because maintenance tasks are in contrast to crucial tickets, not that time-dependent. The workflows are well structured, the responsibilities are defined, and S_5 is *applicable.* Also, S_6 is *applicable* for scenario (A) since we implemented interfaces to the ticket system in the design phase. It is rather *partially applicable* for scenario (B) because interfaces are missing yet, and there are a lot of ways to submit a ticket, as oral, by phone, or digital, which have to be received by a person. Although the wireless network of the university is well-developed, it cannot be expected to be omnipresent. The smartwatches should be therefore equipped with access to mobile networks, and hence S_7 is *partially applicable.* The participants are young and very interested in smartwatches. Nevertheless, in scenario (A), few employees state that they do not like to wear wristwatches and cannot imagine wearing smartwatches during their work regarding S_9. S_{10} is for both scenarios *partially applicable* since all involved people are sure that it is possible to negotiate an agreement with the works council, but this is still owing. Despite the team in scenario (A), which already purchased smartwatches for their work, for scenario (B), the statement S_{11} is at least questionable whether the university authorizes the required financial resources. With the mentioned limitations, smartwatches are applicable and beneficial in both scenarios.

For scenario (C), we already discovered some challenges during the interview with the two heads of the electronic assessment team. This is ultimately reflected during evaluating the framework since, in statement S_1, we have to recap that the employees are distributed over different examination rooms but are very limited in their movement. At all times, they can use their smartphones or are in the direct proximity of a desktop PC running a better-suited text chat application. Smartwatches degenerate to PC or smartphone extensions to increase haptic feedback at an employees' wrist to emphasize incoming notifications. The scenario cannot benefit from smartwatches since no proper mobility can be determined.

To further evaluate the framework, we apply it to another scenario (D) from the industrial production and quality assurance, in which mobile technicians have to operate multiple machines sending notifications about their status on a shop floor collaborating and employees of a quality assurance department (Zenker / Hobert 2019, study 1). Besides S_6, S_8, and S_{10}, all statements are *appropriate* due to the collaboration of mobile machine operators who perform manual work and require access to their digital workspace and need to quickly share information with their colleagues during the guided process. Since employees operate and maintain the machines, smartwatches have to be rugged to address S_8. As in many companies, over time, digital systems grow and are not always well coordinated with each other. It requires some effort to embed all relevant systems and satisfy S_6. Another time-consuming point almost every company has to deal with is a substantial agreement with the works council regarding the collection of personal data and possible surveillance. In this case, it is not solved entirely yet (S_{10}), but open communication and readiness of employees promote this process. Even in this scenario, which goes beyond support, a reasonable conclusion can be drawn and fits the recent experience.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}
(A)	●	●	●	◐	●	●	◐	●	◐	◐	●
(B)	●	●	●	◐	●	◐	◐	●	●	◐	◐
(C)	○										
(D)	●	●	●	●	●	◐	●	◐	●	◐	●

Table 10. Utilization of the smartwatch applicability framework in the four scenarios (a statement is ● applicable, ◐ partially applicable, or ○ not applicable)

2.7 Discussion and Conclusion

In this paper, we addressed the adoption of smartwatch-based IS to assist support employees. As a tool for further investigations, we designed a software artifact applying a design science research inspired approach (Peffers et al. 2007). We first identified and described the problem, including three representative scenarios found in practice through a workshop series and several interviews in previous studies. Complementary to the *smartActivity* artifact (Zenker / Hobert 2019, study 1), we formulated objectives and inferred requirements for an adaption to fit various support scenarios. During the design phase, we involved practitioners and the leader of a university's student IT infrastructure support team. By designing and implementing the necessitated components for *supportWatch* composed of a smartwatch application, a desktop backend, and a server infrastructure, we addressed RQ1. With this, it is possible to cover the original problem of assisting support employees in student IT-infrastructure, lecture hall technology support, and electronic assessment support teams, where an exchange of information is slow, media distortions occur, process support is lacking, and it is difficult for employees to collaborate efficiently.

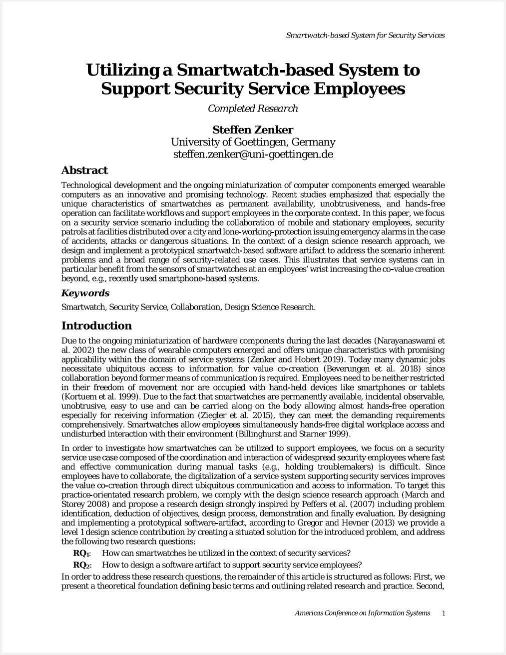
In a demonstration step, we presented our system to practitioners and explained how we integrated smartwatches in their daily-life scenarios. Subsequently, we gathered feedback during two rounds of questionnaires and interviews evaluating a field study. According to the experts, the unique features as workflow guidance based non-interrupting, immediate and location-independent information exchange of *supportWatch* result in an improvement of the process and collaboratively. Inspired by the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014), we categorized the enabling and influencing factors for the adoption of smartwatch-based IS in companies to address RQ2. Based on this, we tackle RQ3 by the proposal of the *Smartwatch Applicability Framework* to provide persons in charge a simple guideline for the potential of the use of smartwatches in their company.

As with any practice-oriented research study, some limitations exist: First, the empirical foundation of the developed meta-artifact is predominantly based on three university scenarios. To address this limitation, we like to apply the *Smartwatch Applicability Framework* at more companies with promising scenarios and transfer *supportWatch* to more use cases. However, we verified the utility of smartwatches for the assistance of support employees and elaborated enabling and inhibiting factors for the adoption and diffusion of this innovative technology in the corporate context. Second, our evaluation is limited as the participants of the evaluation could only test the application for a short time-frame. Hence, we want to conduct a long-term evaluation in the future, including a higher number of participating employees and the impact of inter-team scenarios. For that, a refined instrument can facilitate measuring the various perceptions that individuals may have concerning the adoption of smartwatch-based IS (Moore / Benbasat 1991). This allows assessing the long-term impact of smartwatches in companies and challenges like technostress (Ayyagari et al. 2011).

Nevertheless, for practice, we created an applicable software solution for many support scenarios to assist employees in workflows with innovative technologies. Furthermore, we provide the *Smartwatch Applicability Framework,* which can facilitate companies to draw well-grounded decisions on whether they can benefit from the unique characteristics of smartwatches within their scenarios and workflows. This helps companies to keep pace with the competition through the avoidance of strategic mistakes, which cost a lot of money and time, as well as the consolidation of employees. This promotes the diffusion of smartwatch devices in enterprises. Within the research domain, we accumulated insights and knowledge that can help to understand how to integrate smartwatches into the corporate context and how to design mobile IS based on smartwatches to support employees in workflows. It can be used as a basis for further scientific studies on using smartwatches in enterprise scenarios. We complement theory with enabling and inhibiting factors for the adoption and diffusion of smartwatches in the corporate context. Despite many works that extensively focus on the factors that foster adoption of innovations and implicitly assume that inhibitory factors are merely the opposite of enablers (Cenfetelli 2004), we elaborated enabling and inhibiting factors that we expect to be independent of each another and can coexist. For example, privacy (E_2) is a distinct inhibitor since the sensors of smartwatches can gather person-related data. The necessary negotiation with the works council takes time and complicates the introduction of this innovative technology. However, the incidental use of smartwatches (T_2), for instance, is a big enabler of smartwatch adoption since this unique device characteristic offers additional value. If an incidental operation is not required by employees, this enabler is weakened, and in total, the inhibiting factors like operability (T_{10}) may predominate due to the small form factor. The analysis of influencing factors can help to understand why smartwatches are not yet widely utilized by companies, and we implemented this knowledge in the *Smartwatch Applicability Framework* to facilitate future adoption of smartwatches in the corporate context.

3 Security Service

Utilizing a Smartwatch-based System to Support Security Service Employees



Smartwatch-based System for Security Services

Utilizing a Smartwatch-based System to Support Security Service Employees

Completed Research

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Abstract

Technological development and the ongoing miniaturization of computer components emerged wearable computers as an innovative and promising technology. Recent studies emphasized that especially the unique characteristics of smartwatches as permanent availability, unobtrusiveness, and hands-free operation can facilitate workflows and support employees in the corporate context. In this paper, we focus on a security service scenario including the collaboration of mobile and stationary employees, security patrols at facilities distributed over a city and lone-working-protection issuing emergency alarms in the case of accidents, attacks or dangerous situations. In the context of a design science research approach, we design and implement a prototypical smartwatch-based software artifact to address the scenario inherent problems and a broad range of security-related use cases. This illustrates that service systems can in particular benefit from the sensors of smartwatches at an employees' wrist increasing the co-value creation beyond, e.g., recently used smartphone-based systems.

Keywords

Smartwatch, Security Service, Collaboration, Design Science Research.

Introduction

Due to the ongoing miniaturization of hardware components during the last decades (Narayanaswami et al. 2002) the new class of wearable computers emerged and offers unique characteristics with promising applicability within the domain of service systems (Zenker and Hobert 2019). Today many dynamic jobs necessitate ubiquitous access to information for value co-creation (Beverungen et al. 2018) since collaboration beyond former means of communication is required. Employees need to be neither restricted in their freedom of movement nor are occupied with hand-held devices like smartphones or tablets (Kortuem et al. 1999). Due to the fact that smartwatches are permanently available, incidental observable, unobtrusive, easy to use and can be carried along on the body allowing almost hands-free operation especially for receiving information (Ziegler et al. 2015), they can meet the demanding requirements comprehensively. Smartwatches allow employees simultaneously hands-free digital workplace access and undisturbed interaction with their environment (Billinghurst and Starner 1999).

In order to investigate how smartwatches can be utilized to support employees, we focus on a security service use case composed of the coordination and interaction of widespread security employees where fast and effective communication during manual tasks (e.g., holding troublemakers) is difficult. Since employees have to collaborate, the digitalization of a service system supporting security services improves the value co-creation through direct ubiquitous communication and access to information. To target this practice-orientated research problem, we comply with the design science research approach (March and Storey 2008) and propose a research design strongly inspired by Peffers et al. (2007) including problem identification, deduction of objectives, design process, demonstration and finally evaluation. By designing and implementing a prototypical software-artifact, according to Gregor and Hevner (2013) we provide a level 1 design science contribution by creating a situated solution for the introduced problem, and address the following two research questions:

RQ_1: How can smartwatches be utilized in the context of security services?
RQ_2: How to design a software artifact to support security service employees?

In order to address these research questions, the remainder of this article is structured as follows: First, we present a theoretical foundation defining basic terms and outlining related research and practice. Second,

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Keywords: Smartwatch, Security Service, Collaboration, Design Science Research

Citation: (Zenker 2020, study 3) Utilizing a Smartwatch-based System to Support Security Service Employees. In: Proceedings of the 26th Americas Conference on Information Systems. Salt Lake City, USA: AIS, 1-11.

3.1 Introduction

Due to the ongoing miniaturization of hardware components during the last decades (Narayanaswami et al. 2002), the new class of wearable computers emerged and offers unique characteristics with promising applicability within the domain of service systems (Zenker / Hobert 2019, study 1). Today many dynamic jobs necessitate ubiquitous access to information for value co-creation (Beverungen et al. 2018) since collaboration beyond former means of communication is required. Employees need to be neither restricted in their freedom of movement nor are occupied with hand-held devices like smartphones or tablets (Kortuem et al. 1999). Due to the fact that smartwatches are permanently available, incidental observable, unobtrusive, easy to use, and can be carried along on the body, allowing almost hands-free operation, especially for receiving information (Ziegler et al. 2015), they can meet the demanding requirements comprehensively. Smartwatches allow employees simultaneously hands-free digital workplace access and undisturbed interaction with their environment (Billinghurst / Starner 1999).

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In order to address these research questions, the remainder of this article is structured as follows: First, we present a theoretical foundation defining basic terms and outlining related research and practice. Second, we describe our research method inspired by the design science research framework of Peffers et al. (2007). By applying the framework to our problem domain, we illustrate the results of each step within the design science research approach. Finally, we conclude this article with a discussion of our findings and emphasis on our research contributions for theory and practice.

3.2 Theoretical Foundation and Related Research

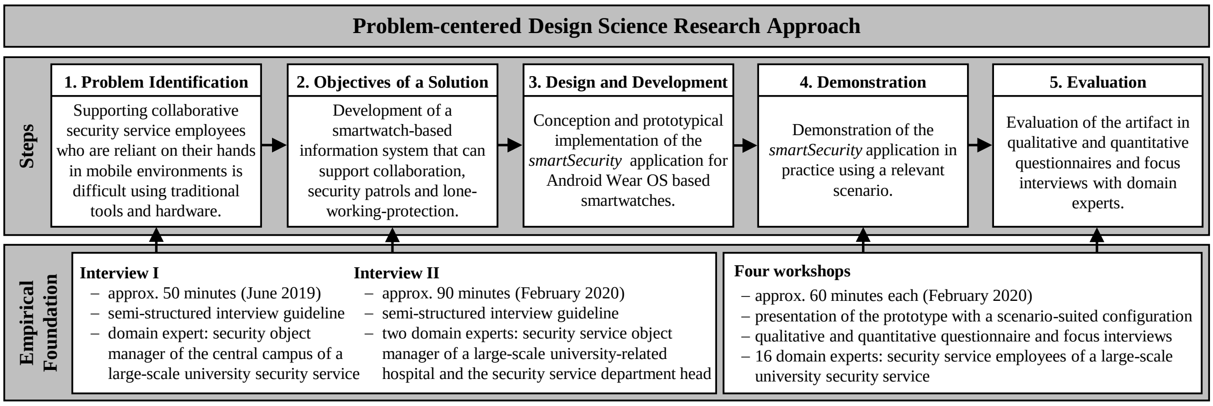
Smartwatches are a special form of mobile computers equipped with various sensors and wireless interfaces in the shape of digital wristwatches (Cecchinato et al. 2018). Since they are operated by a hardware-independent operating system, which can be extended by installable applications, they delimit from other mobile devices with a similar shape like fitness trackers. Smartwatches are worn directly on the users' body, are therefore always available and can demand a users' attention proactively with haptic feedback like vibrations in order to initiate interactions (e.g., react to received notifications), independently of a specific location or time (Boronowsky et al. 2008; Rhodes 1997). Due to the small form factor, smartwatches are usually limited to simple input and output options (Malu / Findlater 2015).

Although most research contributions as Xiao et al. (2014) and Bieber et al. (2013) target technical aspects, first approaches address the deployment of wearable computer within the corporate context (Hobert / Schumann 2017b) in general and smartwatches (Zenker / Hobert 2019, study 1) in particular. In practice, companies presented several smartwatch-based products such as MeisterTask (MeisterLabs GmbH 2020), Hipaax TaskWatch (Hipaax LLC 2020), aucobo (aucobo GmbH 2020), and WORKERBASE (WORKERBASE GmbH 2020), which provide support for the coordination of tasks. Despite this, these products have a limited range of functionality and are not suited for the needs of security services. Anyway, there are already digital smartphone-based solutions for security services as Coredinate (COREDINATE GmbH 2020), and there are thoughts about tracking and sending GPS information from devices and panic buttons in research (Kanagaraj et al. 2013). Nevertheless, to our knowledge, there are neither commercial products nor research contributions utilizing smartwatches to support security service employees so far.

3.3 Research Design

In order to target the research gap and the corresponding problem outlined in the previous section, we apply a problem-centered design science research approach based on the process model of Peffers et al. (2007), as illustrated in Figure 26. We also outline the empirical foundation used for each step accordingly.

First, the artifact development is grounded in the problem identification phase (step 1). For this, we rely on interviews with a security service object manager of a university's central campus, the security service object manager of a university-related hospital, and a security service department head as domain experts. With the security service scenario as the identified real-world problem, we derive functional and non-functional requirements as the objectives of our solution (step 2) based on the interviews. During these interviews, the involved domain experts explained in detail the current security service workflows, and we discussed how smartwatches could be utilized in order to support security service employees in this scenario. According to the research process model, we designed and implemented the conceptual prototype *smartSecurity* based on the elaborated requirements (step 3). Subsequently, in step 4, we demonstrated our software-artifact to 16 security service employees in a series of workshops. For this, we presented a realistic scenario that is close to the employees' daily work. Finally, we queried the opinion of the employees about our system within the security service use case in an evaluation using a questionnaire including seven qualitative and 27 quantitative questions together with several additional focus interviews with selected employees.



1. Problem Identification
Supporting collaborative security service employees who are reliant on their hands in mobile environments is difficult using traditional tools and hardware.

2. Objectives of a Solution
Development of a smartwatch-based information system that can support collaboration, security patrols and lone-working-protection.

3. Design and Development
Conception and prototypical implementation of the *smartSecurity* application for Android Wear OS based smartwatches.

4. Demonstration
Demonstration of the *smartSecurity* application in practice using a relevant scenario.

5. Evaluation
Evaluation of the artifact in qualitative and quantitative questionnaires and focus interviews with domain experts.

Interview I
- approx. 50 minutes (June 2019)
- semi-structured interview guideline
- domain expert: security object manager of the central campus of a large-scale university security service

Interview II
- approx. 90 minutes (February 2020)
- semi-structured interview guideline
- two domain experts: security service object manager of a large-scale university-related hospital and the security service department head

Four workshops
- approx. 60 minutes each (February 2020)
- presentation of the prototype with a scenario-suited configuration
- qualitative and quantitative questionnaire and focus interviews
- 16 domain experts: security service employees of a large-scale university security service

Figure 26. Research design

3.4 Design and Implementation of the *smartSecurity* Application

In this section, we present the design and implementation of the *smartSecurity* prototype. As a result of a Design Science Research approach, we provide a software artifact addressing the security service scenario in practice and extend knowledge about new use cases for smartwatches in theory.

3.4.1 Problem Identification

Due to the high mobility of employees, the interest to operate digital devices hands-free, and the collaborative scenarios, security service appeared as a promising use case for smartwatches. As elaborated during the interviews, the scenario is composed of a security supervisor who is located at a central office organizing the operations of the team and several mobile employees spread over all facilities executing various tasks (e.g., checking and locking properties). Mobile employees are moving in and between the facilities spread over the city by foot or car in order to maintain security at all locations. We identified three security workflows with the potential to be supported by a smartwatch-based service system and illustrated the scenario in Figure 27.

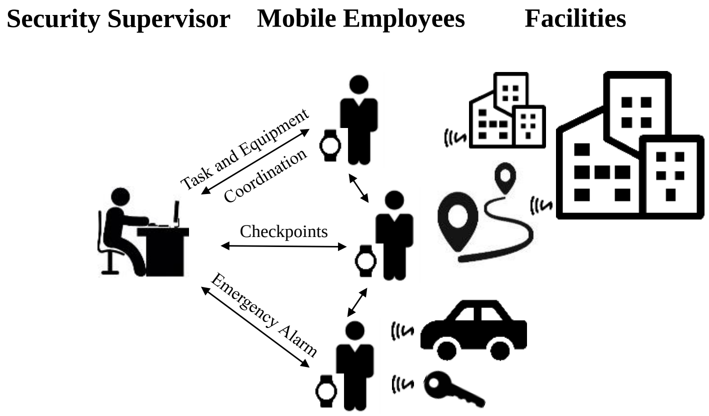


Figure 27. Security service scenario

First, there is the coordination and arrangement of employees, including assignment of tasks, communication of issues, and team organization, which in our case is predominantly done with phones. In addition, mobile employees need to carry keys and other equipment, e.g., torches, protective vests, or pepper spray, which is required to successfully and securely fulfill their tasks. This equipment has to be registered at the security supervisor's office to enable traceability and ultimately prevent loss or abuse. Second, security employees have to close and lock facilities at defined times. For that, there are several routes encompassing relevant locations that are then assigned to a respective mobile employee. While employees are proceeding their routes, at current facilities, windows have to be closed, persons to be escorted, and doors to be locked. In addition, the facility is checked for external damage or signs of burglary. Whenever the examination of a location is done, the responsible employee has to sign presence at a mounted key-based or wireless terminal and to give a written report including occurrences as appropriate. Finally, security employees usually work alone on their tours. In the case of incidents, attacks, or dangerous situations, they are not immediately secured by their colleagues. If they are able to do so, they can use the phone to call the security supervisor and request amplification by colleagues or the police. This communication could take critical minutes and gets impossible in situations of self-defense or unconsciousness.

Recently, smartphone-based systems are introduced to cover some of the mentioned aspects (especially the digitalization of the incident book saves a lot of paper, storage, and time), but due to hardware-related limitations, not all individual needs can be satisfied (for example, digital devices are an additional burden and have to be taken out of the pockets for every operation). Employees can particularly benefit from the unique characteristics of smartwatches. The potential for improvement is driven by three key problems impairing the co-value creation. First, all involved employees have uncertainty about the progress and status of their colleagues. Since they have to work alone, are widely spread, and capabilities of radio would be exceeded with permanent detailed status information, a smartwatch-based system can facilitate the collaboration and provides individual required information instead of unnecessary broadcasts. Second, there are media disruptions having digital, printed, and written representations of the same information (for example, documentation of keys). In addition, it is advantageous for sharing information to have a single digital system unifying different lists at different devices. Third, smartwatches offer comfort to employees in their daily work. On the one hand, smartwatches are similar to common wrist-worn watches, which enables a high acceptance. On the other hand, employees can operate a smartwatch casually to keep their focus on the real world, and their hands remain free for, e.g., arresting somebody.

3.4.2 Objectives of a Solution

Based on the preceded interviews with the security service object manager of the central campus (I-Exp$_1$), the security service object manager of the university related hospital (I-Exp$_2$), the security department head (I-Exp$_3$), and the in the previous section introduced scenarios, we elaborate functional (see Table 11) and non-functional (see Table 12) requirements to describe the objectives of the system to face the security service-related problems. According to the three identified security workflows, we assigned the requirements to the categories collaboration, security patrols, and lone-working-protection.

Collaboration of security employees					
mobile	**RC$_1$**	Receive and display task assignments casually and quietly (hands-free)	stationary	**RC$_7$**	Manage employees and mobile devices
	RC$_2$	Send task acknowledgment (hands-free)		**RC$_8$**	Manage tasks and associated responses
	RC$_3$	Respond to tasks with context-based options		**RC$_9$**	Create and assign tasks with priority
	RC$_4$	Send voice-based messages and provide push-to-talk		**RC$_{10}$**	Provide statistics about occurrences
	RC$_5$	Check in and out employees for timekeeping		**RC$_{11}$**	Manage keys and equipment
	RC$_6$	Register issue and return of keys and equipment			
Security Patrols					
mobile	**RP$_1$**	Report presence and occurrences at checkpoints quickly	stationary	**RP$_4$**	Manage routes and checkpoint locations
	RP$_2$	Provide checkpoint list of the actual route		**RP$_5$**	Visualize route progress, checkpoints, and incidents on a map
	RP$_3$	Navigate easily to the next checkpoint			
Lone-working-protection					
mobile	**RL$_1$**	Request rapidly reinforcement	stationary	**RL$_4$**	Display emergency alarms
	RL$_2$	Detect attacks, inactivity, and incidents automatically			
	RL$_3$	Hands-free emergency alarm			

Table 11. Functional requirements

In the domain of collaboration, “*it would be much nicer if you have a button to connect several people and exchange tasks and acknowledgments instead of calling the people separately which can* *sometimes take 5 to 10 minutes*" (I-Exp$_1$) (RC$_1$, RC$_2$, RC$_9$). Also, "*colleagues should be reminded of tasks by the system until they conclude their report*" (I-Exp$_1$). Since on smartwatches text input seems to be impracticable (Chaparro et al. 2015), context-specific options covering common reports have to be provided (RC$_3$). For this communication, on the one hand, it is important that the device can be operated hands-free, since "*especially in the medical context we often have to detain someone with the full commitment of hands and arms and in this situation, it is not possible to get out a phone to quickly call colleagues*" (I-Exp$_1$) and "*when driving a car, you cannot easily answer the phone, but you can react immediately to notifications on a smartwatch*" (I-Exp$_1$). On the other hand, "*we also take care of security and closure of libraries, where ringtones or calls are undesirable, and vibrations of incoming calls can easily be missed on the phone in your pocket*" (I-Exp$_1$). In addition, "*we do not want other people to witness we use our smartphone*" (I-Exp$_1$) in order to inconspicuously request assistance. To make communication even faster and easier, "*audio messages as report and push-to-talk would be very useful*" (I-Exp$_3$). For the team organization and timekeeping, there is the problem that "*employees sometimes forget to check in and out*" (I-Exp$_1$) what can be done automatically and incidental since the employees wear the smartwatches for their working period (RC$_5$). At the security supervisor's office, "*keys or equipment are issued and returned*" (I-Exp$_1$) and "*and the employee is put into a list to document possible loss or abuse*" (I-Exp$_1$). This also can be done digitally, the smartwatch can be utilized to implement the scan procedure (RC$_6$), and the security supervisor can manage the list in the stationary part of the system (RC$_{11}$). As employers like the university would like to have an overview of occurrences, "*we periodically have to provide statistics*" (I-Exp$_1$), which can be used to optimize workflows and conditions (RC$_{10}$). The requirements RC$_7$ and RC$_8$ are technically needed in order to manage the involved employees and devices as a foundation for the rest of the system.

For security patrols which are checked periodically, "*we have more than 500 checkpoints all over the university placed at, e.g., doors or things that have to be locked strung together to routes*" (I-Exp$_1$), and a digital system can support employees to provide an overview and quickly signal the presence at these locations (RP$_1$, RP$_2$). "*The responsible security supervisor should be able to see the particular progress of the mobile employees*" (I-Exp$_1$) and "*it would be facilitating to see all occurrences and emergency alarms on a map to know immediately which employee is close to the location and could help quickly*" (I-Exp$_1$) (RP$_5$). For that, the security supervisor should be able to add and allocate checkpoints to routes (RP$_4$). "*Especially for new employees or in the case of emergencies, an indication of the target location direction would save critical minutes*" (I-Exp$_3$), which motivates elementary navigation (RP$_3$).

Since the mobile security employees are usually alone on their way and do not have immediate assistance from their colleagues, "*as a lone-working-protection, we require an opportunity to quickly request help*" (I-Exp$_1$) (RL$_1$). "*It is too slow to get out a phone and to call someone who does not know exactly where you are*" (I-Exp$_1$). Furthermore, "*operating a device with your hands is not possible in dangerous situations, e.g., fixating someone*" (I-Exp$_1$), and for that, "*we would like to issue emergency alarms hands-free*" (I-Exp$_1$) (RL$_3$). On the other side, "*it is stressful for the security supervisor to check if anyone does not move for more than a quarter of an hour*" (I-Exp$_1$), which can be detected automatically by a device located at an employees' wrist and equipped with a broad range of sensors. In this way, it is possible, in fact, to determine attacks and incidents (RL_2). The emergency alarms should immediately be displayed to the "*supervisor who can immediately react and call the police if necessary*" (I-Exp_1) (RL_4).

RNF_1	At least 12 hours of battery life on the mobile device to sustain a complete shift
RNF_2	Robustness of the mobile device to scratches, shocks, and impacts due to mechanical stress
RNF_3	Reliable network connectivity and sufficient data volume
RNF_4	No acquisition of unnecessary employee-related data

Table 12. Non-functional requirements

As *"our shifts can last from 8 or 9 up to 12 hours*" (I-Exp_1) and it would be an unnecessary effort to return the smartwatches for charging in between, and consequently, the battery has to last at least one shift (RNF_1). In "*situations where people have to be held or accompanied*" (I-Exp_1), which predominantly occur in the medicinal departments of the university where mental illness or medication is a factor, smartwatches must not be damaged to reliable provide their functionalities (RNF_2). Especially, to assure constant and fast exchange of information, "*we cannot rely on wireless networks since at the critical moment it may lack coverage*" (I-Exp_1) and adequate wireless technologies with the highest reliability, coverage and "*sufficient data volume to avoid loss of the mobile network"* (I-Exp_2) have to be selected (RNF_3). Since smartwatches can track a variety of person-related data, employees must be transparently informed about the advantages and disadvantages. "*Because the employees are working alone, this is not to monitor them, but it is for their safety and that nothing happens to them*" (I-Exp_1) (RNF_4).

By means of these requirements, the security supervisor can considerably be relieved since the centralized phone-based communication turns into a digital smartwatch-supported collaboration enabling direct communication between the mobile employees. Unnecessary calls can be prevented, and the required time for a long sequence of (abortive) calls is notably reduced. The efficiency of the workflows is increased because especially mobile employees can now directly find the counterpart for tasks. Furthermore, the security supervisor does not have to collect and register the reports about occurrences to the incident book anymore since every employee can independently enter and work on reports. Additional, workflows that do not often occur in everyday life (e.g., large scale operations) can be supported. Finally, the automated detections of attacks, inactivities, and incidents can benefit from the smartwatch sensors, which are located at an employees' wrist and are directly connected to the body, not as with smartphones, which are put to any pocket and have some risk of being forgotten somewhere.

3.4.3 Design and Development

For the design and development of the *smartSecurity* prototype, we rely on the meta software-artifact *smartActivity* (Zenker / Hobert 2019, study 1), supporting employees in collaborative workflows within the industrial sector. It is composed of a *Wear OS* smartwatch application and a web-based backend that can be used at a desktop setting or mobile devices like smartphones. We utilize the first strategy proposed by Iivari (2015), taking the general solution concept *smartActivity* as the foundation and instantiate it to our special solution concept by modification and extension. In this way, especially RC_1, RC_2, RC_3, RC_7, RC_8, and RC_9 are already met, and the characteristics of the security scenario necessitate just a few modifications. In order to address the remaining requirements, we equipped the mobile security employees with smartwatches and provided the stationary security supervisor access to the web-based backend. In addition, we assign NFC-tags to checkpoints located in the facilities and equipment like keys (see Figure 27). NFC-tags are cheap, can be placed inconspicuously with little effort, and can quickly and without contact be recognized by the sensors of smartwatches. The programmed ID can be attributed to the location or equipment easily and can trigger subsequent actions (e.g., the input of a report). According to the defined requirements, the implementation of the mobile smartwatch application of *smartSecurity* is illustrated in Figure 28.

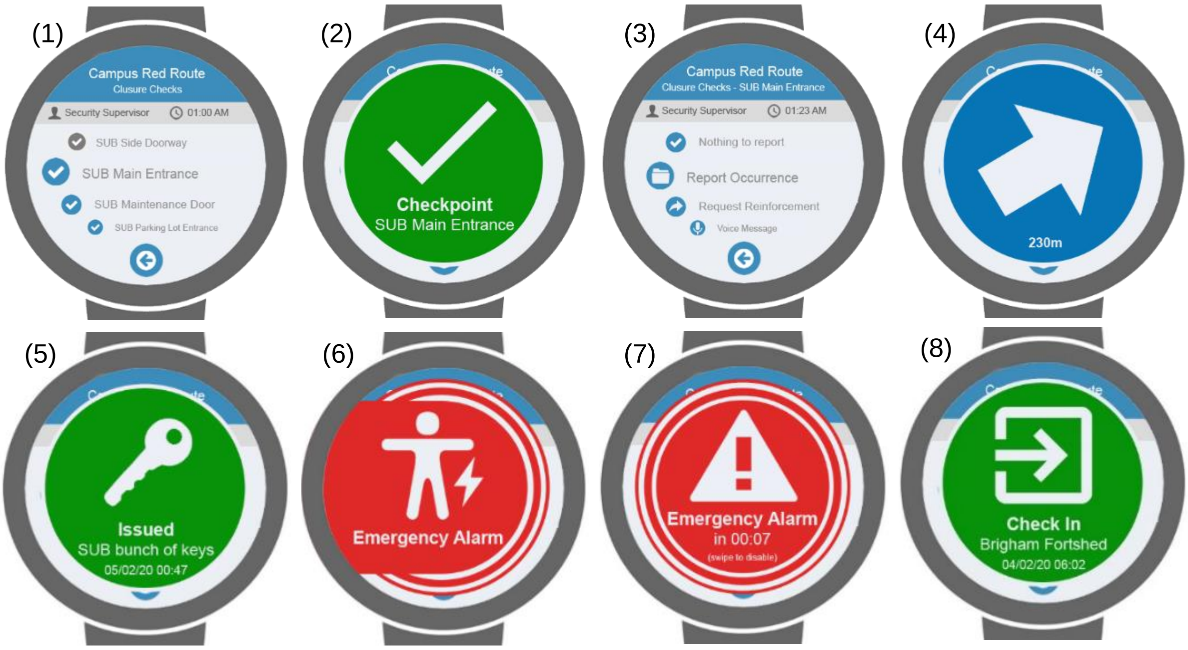
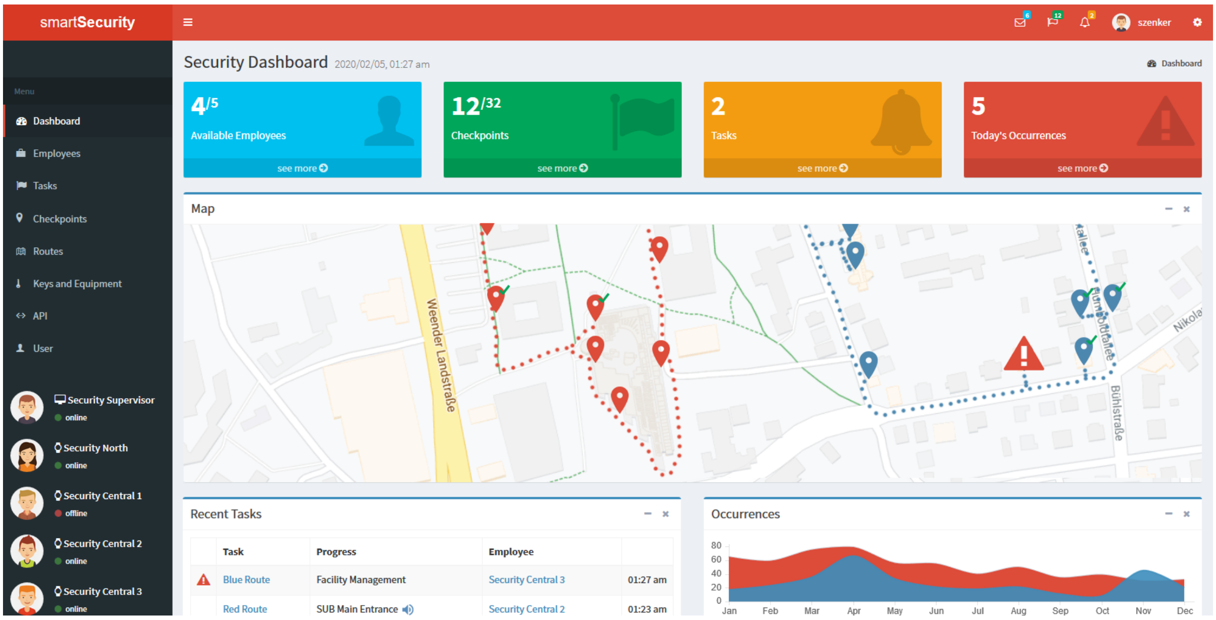


Figure 28. *smartSecurity* smartwatch application

The first screenshot (see Figure 28 (1)) shows the sequence of checkpoints related to the actual route (RP_2), which can be constructed with the workflow builder in the backend. If desired, the checkpoints can be shuffled randomly to make the employees appear unpredictably at the locations. A mobile security employee receives a route as a task (RC_1) and can see which checkpoints are processed (gray) and which are upcoming. At a targeted location marked with an NFC-tag, the smartwatch can be used to scan the tag (see Figure 28 (2)), signing an employees' attendance at this specific location and time (RP_2). Automatically, *smartSecurity* registers this procedure and provides context-specific options (RC_3) to conclude the current location and give a report to the security supervisor (see Figure 28 (3)). In the case, there are occurrences to report, the options are categorized in a tree structure to find the appropriate entry as fast as possible and without the need for text input. If required, one option, which is easy to access, requests reinforcement in dangerous situations, and the security supervisor plus colleagues in the proximity are informed respectively (RL_1). In addition, there is the option to record a voice message using the microphone of the smartwatch (RC_4) and to listen to received voice messages with earbuds connected through Bluetooth. Whenever a location is completed, the checkpoint overview is displayed, and based on the GPS receiver of the smartwatch, the direction to the next checkpoint and the distance can be accessed (see Figure 28 (4)). Since the checkpoints are close to each other, this elementary navigation system is sufficient and fits appropriately to the small screen of a smartwatch (RP_3). It is meant especially for new employees who do not know the routes and providing a quick estimate of direction in emergencies. Figure 28 (5) shows the ability of *smartSecurity* to register the issue and return of keys and equipment (RC_6). The assigned NFC-tags are scanned with the employee's associated smartwatch, and automatically the equipment is allocated by the system. This prevents possible loss or abuse and enables automated documentation. Concerning the lone-working-protection, we implemented two different approaches. On the one hand, an emergency alarm can be triggered by intention. For this, an employee has to swipe from the left end of the screen to the right side and to confirm the intention with a tap or can use a designated hardware button (see Figure 28 (6)). In order to make the procedure hands-free and usable in situations where an employees' hands are not available, another trigger is a gesture turning the smartwatch three times back and forth, confirming with a short up and down motion (RL_3). On the other hand, there is an automated system as the motion sensors of a smartwatch located at the favorable location at an employees' wrist can detect heavy impacts and lack of motion attributed to attacks, inactivities, or accidents (RL_2). Whenever the automated system is activated, the employee gets a notification (see Figure 28 (7)) highlighted with vibrations and an alarm sound to deactivate it within some seconds in the case of a false alarm. The number of seconds can be configured in the backend since the demands are depending strongly on the scenario. Finally, employees can use their smartwatches to check in and out at work for timekeeping (RC_5). We attach an NFC-tag to an employees' ID card, which can initially be scanned to assign it.

The security supervisor can log in to the *smartSecurity* web-based backend with individual credentials using a browser. Figure 29 shows the dashboard, which provides an overview of the current situation. At the top, the security supervisor gets access to the integrated message system and can configure the system by the user profile. At the left panel, the menu and all registered security employees with their actual status are displayed. Through the menu, the security supervisor can manage the employees and deployed devices (RC_7), create tasks for specific or a group of employees (RC_9), which next appear at the particular smartwatches. In addition, the GPS coordinates of checkpoint locations with their NFC-tag IDs can be managed manually by using a map and composed to a route or workflow using the enhanced workflow builder (RP_4). Furthermore, NFC-tags assigned to equipment can be listed and managed (RC_{11}). At the top of the main panel, several characteristic numbers are displayed to enable fast access to the actual situation. This includes the number of actually available security employees, the number of processed checkpoints in relation to the routes, which are due at the moment, the number of tasks assigned to the security supervisor, and the number of occurrences of the day. Below we implemented a map showing all routes, including the checkpoint locations (RP_5 and RL_4). Checkpoints that are already processed are indicated with a green check. In addition, occurrences and emergency alarms are highlighted on the map beside a popup in the browser in order to enable a quick reaction. A click on an emergency or a checkpoint label provides additional information and the functionality to forward and assign mobile employees to the corresponding task. The progress of routes and workflows and the respective recent task is listed at the main panel left bottom. This list is sorted by priority, and voice messages can be retrieved. Besides, on the right side, we implemented a plot of occurrences for the last months for each route (RC_{10}). The data is recorded automatically in the background, and the plot can be configured for scenario-specific needs.



	Task	Progress	Employee	
⚠	Blue Route	Facility Management	Security Central 3	01:27 am
	Red Route	SUB Main Entrance 🔊	Security Central 2	01:23 am

Figure 29. *smartSecurity* web-based backend

3.4.4 Demonstration

Previously to the evaluation, we presented the *smartSecurity* prototype to 16 security service employees (15 males, 1 female), including supervisors and managers with years of experience. For that, we configured the software to fit the realistic scenario of the security service at a large-scale university's facilities. As depicted in Figure 29, we have a security supervisor operating the *smartSecurity* web-backend and four mobile employees equipped with smartwatches. Two of the mobile employees are assigned to the red and blue routes, respectively. We exemplary defined several checkpoints by reasonable coordinates, which are shown at the map overview and in the smartwatch checkpoint list, as can be seen in Figure 28 (1). Furthermore, we simulated an emergency alarm, as shown in Figure 28 (6), which is yet to be handled. In this way, we demonstrated our ideas to implement smartwatches in security service workflows with the prototype pragmatically and easily understandable to the experts within the security service domain.

3.4.5 Evaluation

In order to obtain feedback and insights from domain experts, we conducted a study with the participants of the demonstration. The surveyed employees have a long experience within security services and stated 5.75/7 for their affinity to new technologies and 3.88/7 for their experience with smartwatches as a self-appraisal (we rely on a scale of seven gradations with 1 as minimal and 7 as maximal value). First, we focused on the characteristics of smartwatches and asked the participants how important these attributes are in their daily work. The results are illustrated in Figure 30 (left) and fluctuate around 6/7, indicating high relevance and suitability. Especially mobility seems to be very important for security services. Supplementary, we liked to know how often security service employees estimate to use the smartwatch instead of putting their smartphones out of their pockets. On the one hand, a value of 4.19/7 shows an additional value of smartwatches versus smartphones. *“We have the technology directly at our wrists”* (Q-Exp$_{15}$), it is *“small and compact”* (Q-Exp$_{4}$), leading to *“reduced burden at the body”* (Q-Exp$_{2}$) and *“we have both hands free and can concentrate on our tasks than on a smartphone”* (Q-Exp$_{5}$ and Q-Exp$_{13}$). In particular, during high frequently repeating tasks like visiting checkpoint locations, *“it is very relieving to scan the checkpoints quickly and to keep the smartphone in the pockets”* (Q-Exp$_{6}$). On the other hand, it emphasizes that smartwatches cannot cover all smartphone characteristics. First and foremost, *“we have to write reports, and the displays of smartwatches are too small to input text properly”* (Q-Exp$_{7}$). In addition, *“we like to take pictures of situations, open doors or external damage”* (Q-Exp$_{1}$), which is not possible with smartwatches due to the lack of a camera.

Subsequently, we asked for an assessment of the relevance of the requirements that we have elaborated, which is illustrated on the right side of Figure 30. Again high values can be observed, indicating a high relevance of our system for the security service scenario. Especially requirements concerning the lone-working-protection using the smartwatch sensors are rated with values almost exceeding the maximum. Also, the revised process of scanning the checkpoints was well received. New functions like the navigation to the next checkpoint (which just works properly outside due to the availability of GPS and not in buildings due to multiple levels necessitating a vertical dimension) or push-to-talk are perceived as nice to have but are inferiorly evaluated. As we have fewer security supervisors in the sample, functions like the management of routes and checkpoints or the abstract collaboration of employees are neglected.

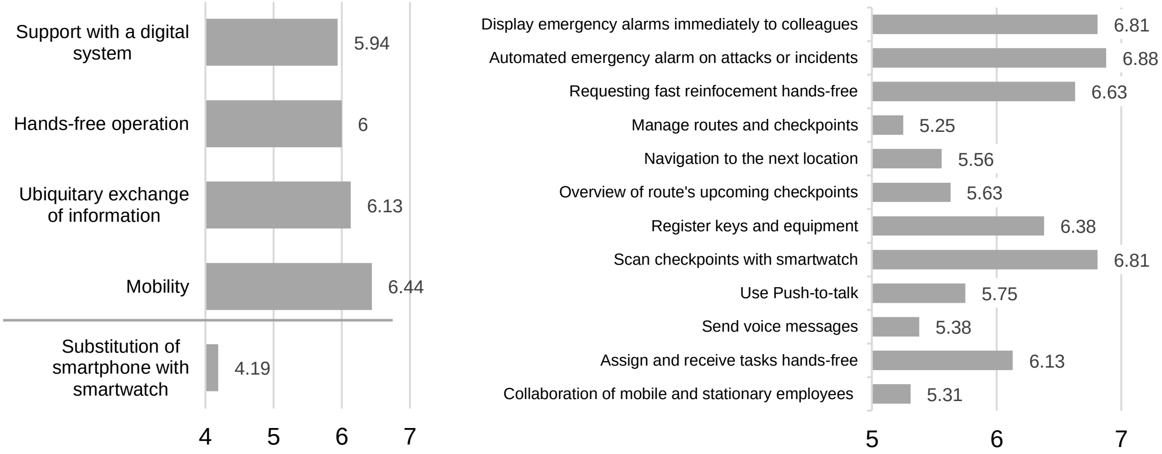


Figure 30. The relevance of smartwatch characteristics and requirements

The major advantage of smartwatch-based systems is that *"procedures can be processed more easily and quickly"* (Q-Exp$_1$ and Q-Exp$_5$), *"hands remain free"* (Q-Exp$_2$, Q-Exp$_7$, Q-Exp$_{10}$, and Q-Exp$_{15}$), but there is still *"quick digital access to information"* (Q-Exp$_4$ and Q-Exp$_5$), which *"makes the work much easier and less complex"* (Q-Exp$_1$ and Q-Exp$_8$). For example, it is possible to *"request reinforcement without being seen or anybody getting worried"* (Q-Exp$_{10}$). *"The security service employee is happy with anything to not have to carry along – smartwatches are very beneficial for that since they are small and lightweight"* (Q-Exp$_1$) and *"smartwatches can replace a variety of devices such as radio, mobile phone, and beeper"* (Q-Exp$_3$). Anyhow, employees desired to have *"more range of the NFC-tags at the checkpoints that you can scan them while walking"* (Q-Exp$_{11}$) and to *"synchronize the smartwatch with the smartphone to have text input and a camera for reports"* (Q-Exp$_2$). *"Maybe it is possible to use speech recognition"* (Q-Exp$_2$).

As usual for new information technologies, there are concerns about *"surveillance of employees"* (Q-Exp$_{13}$ and Q-Exp$_{12}$) whereby the fear of it was rated with 4.25/7, which averages paranoid individuals and employees who do not care about this topic at all. Besides, there are some hardware-related concerns about *"display size for older people with bad eyes"* (Q-Exp$_{11}$, Q-Exp$_6$, and Q-Exp$_4$) (the score for that the display has an appropriate size is 4.88/7), *"battery life for long shifts"* (Q-Exp$_9$, Q-Exp$_7$, and

Q-Exp$_5$), and *“ruggedness of the watch in physical situations”* (Q-Exp$_6$, Q-Exp$_5$, Q-Exp$_1$). Due to *“explosion hazard in, e.g., lacquer rooms, we have to doff the smartwatches every time”* (Q-Exp$_1$). In the organizational domain, it is remarked that *“hygiene is important, and I cannot imagine giving the watch to colleagues, because you are sweating”* (Q-Exp$_1$). Hence, individual smartwatches are recommended. For the introduction of smartwatches, *“the executive management must be willing to invest in innovative technologies*” (Q-Exp$_5$, Q-Exp$_6$, and Q-Exp$_{15}$). Supplementary, *“privacy has to be negotiated with the worker’s council”* (Q-Exp$_{12}$). Furthermore, *“charging trays are required to ensure continuous reliability”* (Q-Exp$_4$ and Q-Exp$_5$), and a *“stable wireless network connection equipped with appropriate data volume”* (Q-Exp$_4$ and Q-Exp$_2$) is wanted. *“Blessedly wireless networks on smartwatches are less endangered than smartphones to be used for private matters like streaming videos during working hours”* (Q-Exp$_1$).

3.5 Discussion and Conclusion

In this paper, we addressed the digital support of security service employees with a smartwatch-based service system. For that, we designed the software artifact *smartSecurity* applying a design science research approach inspired by Peffers et al. (2007). We first described the security service scenario found in practice. Based on preceding interviews, we formulated objectives and inferred requirements for a subsequent development process addressing RQ1. Utilizing the software meta-artifact *smartActivity* (Zenker / Hobert 2019, study 1), we designed and implemented necessitated modifications and extensions for *smartSecurity* composed of a smartwatch application, a desktop backend, and a server infrastructure. Besides the introduced scenario, with our solution, it is possible to cover similar scenarios with the problem of assisting security service employees, where an exchange of information is slow, media distortions occur, process support is lacking and it is difficult for employees to collaborate efficiently. With the presented conceptual prototype, we addressed RQ2 and validated the utility during the evaluation. According to the experts, the unique characteristics of smartwatches can facilitate their daily work and have added value compared to a smartphone (they indicated a 6.19/7 to use the presented system).

As usual for practice-oriented research studies, there are some methodical limitations. First, the empirical foundation of the developed software artifact is merely based on one security scenario and two interviews with three domain experts. In order to address this limitation, we are planning to test and evaluate *smartSecurity* in more security service scenarios of companies during our future research. However, the presented evaluation verified the utility of smartwatches for the assistance of security service employees across multiple security service teams. Since the evaluation results are exceeding positive, we certainly take novelty effects due to the high interest in smartwatches into account and may repeat the questionnaire after some time of experience. Furthermore, just one female security service employee attended our evaluation. From our experience, women have slightly different demands on mobile devices, especially when they are worn on the body. The number of women in studies, although our excerpt is a realistic scale for the gender distribution for security services, in reality, should be increased. Second, our evaluation is limited as we presented the application to the participants for a short time-frame during the workshops. Hence, a long-term evaluation, including a higher number of participating employees who can test the system in their daily life, can be part of future studies. In addition, the *usabilityWatch* framework (Zenker / Hobert 2020, study 6) can be applied to generate insights in order to improve the usability of our application.

Nevertheless, we created an applicable software solution for a broad range of security service scenarios to support employees with innovative technologies in practice (employees rated the idea to utilize smartwatches within the domain of security service with 5.81/7 and the predicted ease of their daily work with 5.88/7). It may be used in combination with other devices like smartphones to, e.g., gain accessibility of a camera if required. Within the research domain, we contributed a level 1 design science software artifact (Gregor / Hevner 2013), which coincidently forms the starting point for a level 2 contribution, identifying design guidelines by extension, application, evaluation, and finally generalization to more scenarios.

4 Support of mobile Employees Executing Manual Work

Designing Smartwatch-based Information Systems to Support Mobile Employees Executing Manual Work

Designing Smartwatch-based Information Systems to Support Mobile Employees Executing Manual Work

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During the last decades, smartwatches emerged as an innovative and promising technology and hit the consumer market due to the accessibility of affordable devices and predominant acceptance caused by the large similarity to common wristwatches. With the unique characteristics of permanent availability, unobtrusiveness, and hands-free operation, they can furthermore assist (mobile) employees who have to execute manual work and have been excluded so far from the benefits of the digitalization. Hence, this paper focuses on how to design smartwatch-based IS to support workflows in the corporate context which can facilitate the daily work of numerous employees and make processes more efficient for companies. During a design science research approach, smartwatch-based software artifacts are designed and evaluated in use cases of production, support, security service, as well as logistics, and a nascent design theory is proposed to complement theory according to mobile IS research. The evaluation shows that on the one hand smartwatches have huge potential to assist employees with a fast and ubiquitous exchange of information, instant notifications, collaboration, and workflow guidance while they can be operated incidentally during manual work. On the other hand, the design of smartwatch-based IS is a crucial factor for a long-term successful deployment in companies, and especially limitations according to the small form-factor, general conditions, acceptance of the employees, and legal regulations have to be addressed appropriately.

Keywords *– Smartwatch; Process support; Design science research; Design theory*

Abstract: During the last decades, smartwatches emerged as an innovative and promising technology and hit the consumer market due to the accessibility of affordable devices and predominant acceptance caused by the considerable similarity to common wristwatches. With the unique characteristics of permanent availability, unobtrusiveness, and hands-free operation, they can furthermore assist (mobile) employees who have to execute manual work and have been excluded so far from the benefits of the digitalization. Hence, this paper focuses on designing smartwatch-based IS to support workflows in the corporate context, facilitating the daily work of numerous employees, and making processes more efficient for companies. During a design science research approach, smartwatch-based software artifacts are designed and evaluated in use cases of production, support, security service, as well as logistics, and a nascent design theory is proposed to complement theory according to mobile IS research. The evaluation shows that, on the one hand, smartwatches have enormous potential to assist employees with a fast and ubiquitous exchange of information, instant notifications, collaboration, and workflow guidance while they can be operated incidentally during manual work. On the other hand, the design of smartwatch-based IS is a crucial factor for successful long-term deployment in companies, and especially limitations according to the small form-factor, general conditions, acceptance of the employees, and legal regulations have to be addressed appropriately.

Keywords: Smartwatch, Process support, Design science research, Design theory

Citation: (Zenker et al. 2020a, study 4) Zenker, S.; Hobert, S.; Schumann, M.: Designing Smartwatch-based Information Systems to Support Mobile Employees Executing Manual Work. Under Review.

4.1 Introduction

During the ubiquitous process of digitalization in the last decades, the introduction of digital devices and information systems change work in the corporate context. On the one hand, they support employees and facilitate work. On the other hand, they make processes more efficient for employers (Parviainen et al. 2017). Nevertheless, some sectors are not covered due to previous technical limitations, and IS cannot unfold their full potential. Mobile employees executing manual work at different locations cannot be digitally supported by traditional hardware and tools unless they interrupt their current work to operate hand-held devices (Zenker / Hobert 2019). Due to the ongoing miniaturization of hardware components during the last decades (Narayanaswami et al. 2002), the new class of wearable computers emerged and offered unique characteristics with promising applicability (Billinghurst / Starner 1999). Today many dynamic jobs necessitate ubiquitous access to information, and employees need to be neither restricted in their freedom of movement nor are occupied with hand-held devices like smartphones or tablets (Kortuem et al. 1999). Since smartwatches are permanently available, incidental observable, unobtrusive, easy to use, and can be carried along on the body, allowing almost hands-free operation, especially for receiving information (Ziegler et al. 2015), they can meet the demanding requirements comprehensively. In contrast to other wearable computers (e.g., smart glasses), smartwatches reached market maturity, recently hit the consumer market, exhibit a high acceptance in the social environment, and the users feel comfortable wearing the device due to the high similarity to ordinary watches (Choi / Kim 2016).

Nevertheless, new challenges, like the visualization of information on small displays, arise due to smartwatches' unique characteristics (Blumenstein et al. 2016; Forman / Zahorjan 1994). To investigate how smartwatch-based IS have to be designed to support mobile employees executing manual work, we focus on the use cases production, support, security service, and logistics. These are identified in empirical studies and are composed of the interaction and collaboration of widespread mobile employees in which fast and effective communication during manual tasks (e.g., repairing a machine or holding troublemakers) is difficult. To target this practice-orientated research problem, we comply with the design science research approach (March / Storey 2008) and propose a research design composed of five cycles, each inspired by the methodology of Peffers et al. (2007), including problem identification, deduction of objectives, design process, demonstration and finally evaluation. By traversing the cycles and gathering design knowledge, we generalize the emerged problem and the solution formulated in design principles and address the following research question by finally proposing a nascent design theory:

> **RQ:** How to design a smartwatch-based information system to support mobile employees executing manual work in collaborative corporate processes incidentally?

To address this research question, the remainder of this article is structured as follows: First, we provide a theoretical foundation, including basic definitions as well as related work and practice. Second, we describe the research method composed of five design science cycles, each based on the research process of Peffers et al. (2007). We describe the design and implementation of a software artifact in the first four cycles covering various scenarios that emerged from practice. In the fifth cycle, we generalize our findings, develop a meta software artifact, and establish a nascent design theory for the support employees executing manual work with a smartwatch-based IS in the corporate context since we achieved a saturation of the design knowledge. Finally, we discuss our findings and conclude this article emphasizing our research contributions for theory and practice.

4.2 Theoretical Foundation and Related Work

As a product of new demands on mobility and technological progress, including continuing miniaturization of computer components (Peercy 2000), the category of wearable computer emerged in the last decades (Boronowsky et al. 2008). Wearable devices are directly worn on the users' body and hence provide unique characteristics as they are permanently active and designed for mobile use (Rhodes 1997; Starner 2001; Dvorak 2007; Witt 2007). These microcomputers can assist the user in a broad range of everyday activities or work processes and assist them through (proactive) support (Dvorak 2007). The class of wearable computer is composed of clothing with integrated electronic systems and devices like smart glasses and smartwatches.

Smartwatches currently dominate the wearable computer market due to their positive attitude and perceived values (Hsiao / Chen 2018; Rawassizadeh et al. 2014). They exhibit a high acceptance in the social environment, and the users feel comfortable wearing the device due to the high similarity to ordinary watches (Choi / Kim 2016). Smartwatches are assembled of standard computer hardware such as a processor, memory, and battery. They are also equipped with various sensors to perceive the environment and wireless interfaces for communication (e.g., W-LAN, Bluetooth, or GSM). Besides, they can be operated with a touchscreen, voice control, motion gesture control, or several hardware buttons as well as a digital lunette (Bieber et al. 2012; Chuah et al. 2016; Pascoe / Thomson 2007).

Smartwatches delimit from other mobile devices with a similar shape like fitness trackers since they run a hardware-independent operating system, which can be extended by installable applications (Rawassizadeh et al. 2014). Although smartwatches can be coupled with a smartphone and interplay with the remote application, we exclusively consider standalone devices rather than smartphone accessories due to the restrictive dependence of another device (Krey et al. 2016). In this paper, we rely on our following definition linking all relevant aspects of a smartwatch:

> A **smartwatch** is a standalone, miniaturized computer in the form of a wristwatch equipped with a touchscreen as well as hardware buttons for operation, various sensors to gather information about the real-world context, and wireless interfaces for communication. It runs a hardware-independent operation system which functionality can be extended by custom applications.

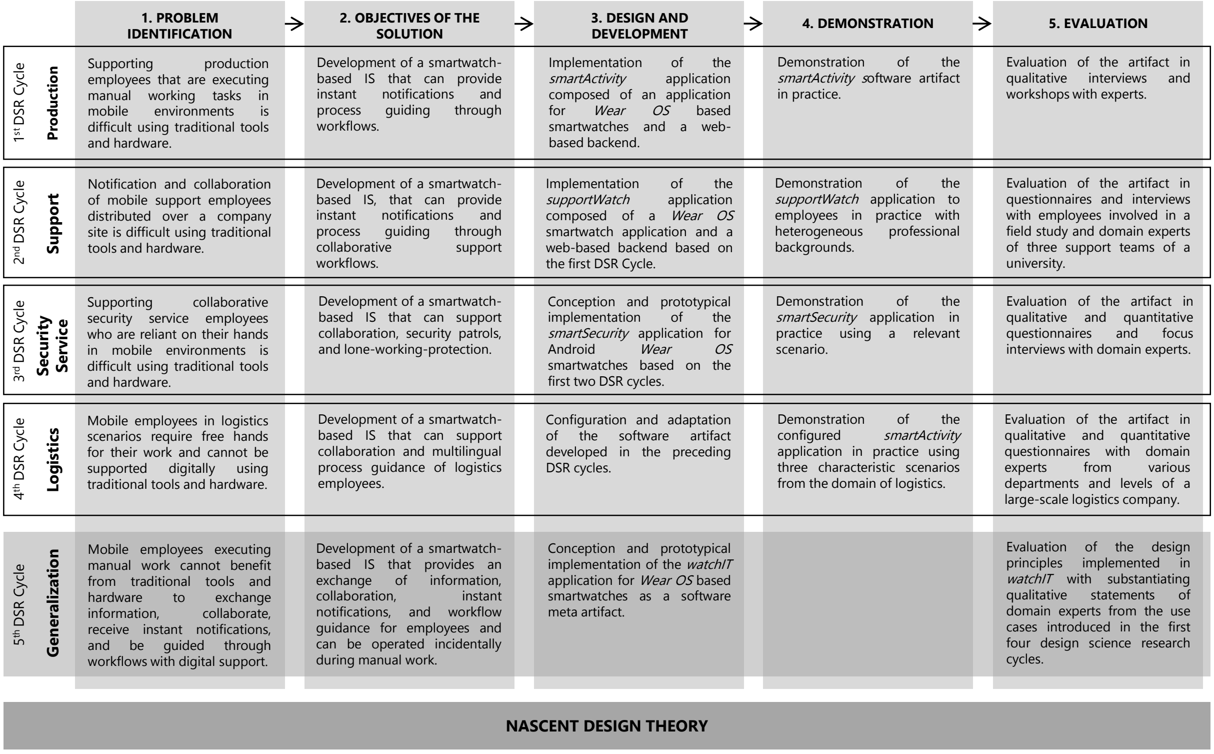
Smartwatches are worn directly on the users' body, are always available, and can therefore demand a users' attention proactively with haptic feedback in the form of vibrations to initiate interactions (e.g., reaction to a notification), independently of a specific location or time (Boronowsky et al. 2008; Jiang et al. 2015; Rhodes 1997). Nevertheless, smartwatches are usually limited to simple input and output options during the operation through a user due to the small form factor (Malu / Findlater 2015). Besides, a smartwatch can permanently gather information about the environment (e.g., for context detection) or the person wearing it in the background using, for example, accelerometers, gyroscopes, microphones, optical sensors (e.g., for pulse measurement), contact sensors (e.g., for temperature measurement), barometers, as well as ambient light sensors (Reeder / David 2016).

The utilization of smartwatches in the corporate context is a recent research subject and can take many different forms. Research on wearable computers started more than 50 years ago (Thorp 1998; Rhodes 1997). Most research contributions target (1) technical aspects like sensor requirements for activity recognition (Bieber et al. 2013) or expanded input expressivity through mechanical interaction (Xiao et al. 2014) on smartwatches, (2) designing applications in private or business contexts such as a smart-glasses-based learning system (Hobert / Schumann 2017b), (3) the added value of wearable computers like studies about augmented reality-based information systems (Berkemeier et al. 2019), a smart glasses-based process modeling recommender system (Fellmann et al. 2018), industrial deployment of wearable computer in the industry (Lukowicz et al. 2007), or the use of wearable and augmented reality technology in industrial maintenance work (Aromaa et al. 2016) as well as (4) usability aspects regarding smartwatch applications like the *usabilityWatch* framework (Zenker / Hobert 2020). The unique characteristics enable smartwatches to allow permanent access to the digital workplace, inform employees proactively, strengthen collaboration with an immediate exchange of information, guide employees with respect to the context through processes, and support workflows in an incidental and hands-free way which was not possible with recent hardware. This is particularly important for mobile employees performing manual work (Satyanarayanan 1996; Yuan et al. 2010).

In the practical domain, some companies also presented approaches in the form of several smartwatch-based products such as MeisterTask (MeisterLabs GmbH 2020), Hipaax TaskWatch (Hipaax LLC 2020), aucobo (aucobo GmbH 2020), and WORKERBASE (WORKERBASE GmbH 2020). These products can manage tasks, show notifications of the enterprise systems, or provide special smartwatch devices made for industrial use. However, to the best of our knowledge, available products have a limited range of functionality, do not provide any scientific background, or are not eligible for scientific studies since the source code cannot be accessed.

4.3 Research Design

With the ultimate goal to understand how to design smartwatch-based information systems to support mobile employees executing manual work in the corporate context, we present a mixed-methods research design. We traverse a design science process composed of five design cycles until saturation of design knowledge is reached, as illustrated in Figure 31. In the end, we propose a nascent design theory, according to Gregor / Jones (2007), as a level three targeted design science contribution (Gregor / Hevner 2013).



	1. PROBLEM IDENTIFICATION	2. OBJECTIVES OF THE SOLUTION	3. DESIGN AND DEVELOPMENT	4. DEMONSTRATION	5. EVALUATION
1st DSR Cycle **Production**	Supporting production employees that are executing manual working tasks in mobile environments is difficult using traditional tools and hardware.	Development of a smartwatch-based IS that can provide instant notifications and process guiding through workflows.	Implementation of the *smartActivity* application composed of an application for *Wear OS* based smartwatches and a web-based backend.	Demonstration of the *smartActivity s*oftware artifact in practice.	Evaluation of the artifact in qualitative interviews and workshops with experts.
2nd DSR Cycle **Support**	Notification and collaboration of mobile support employees distributed over a company site is difficult using traditional tools and hardware.	Development of a smartwatch-based IS, that can provide instant notifications and process guiding through collaborative support workflows.	Implementation of the *supportWatch* application composed of a *Wear OS* smartwatch application and a web-based backend based on the first DSR Cycle.	Demonstration of the *supportWatch* application to employees in practice with heterogeneous professional backgrounds.	Evaluation of the artifact in questionnaires and interviews with employees involved in a field study and domain experts of three support teams of a university.
3rd DSR Cycle **Security Service**	Supporting collaborative security service employees who are reliant on their hands in mobile environments is difficult using traditional tools and hardware.	Development of a smartwatch-based IS that can support collaboration, security patrols, and lone-working-protection.	Conception and prototypical implementation of the *smartSecurity* application for Android *Wear OS* smartwatches based on the first two DSR cycles.	Demonstration of the *smartSecurity* application in practice using a relevant scenario.	Evaluation of the artifact in qualitative and quantitative questionnaires and focus interviews with domain experts.
4th DSR Cycle **Logistics**	Mobile employees in logistics scenarios require free hands for their work and cannot be supported digitally using traditional tools and hardware.	Development of a smartwatch-based IS that can support collaboration and multilingual process guidance of logistics employees.	Configuration and adaptation of the software artifact developed in the preceding DSR cycles.	Demonstration of the configured *smartActivity* application in practice using three characteristic scenarios from the domain of logistics.	Evaluation of the artifact in qualitative and quantitative questionnaires with domain experts from various departments and levels of a large-scale logistics company.
5th DSR Cycle **Generalization**	Mobile employees executing manual work cannot benefit from traditional tools and hardware to exchange information, collaborate, receive instant notifications, and be guided through workflows with digital support.	Development of a smartwatch-based IS that provides an exchange of information, collaboration, instant notifications, and workflow guidance for employees and can be operated incidentally during manual work.	Conception and prototypical implementation of the *watchIT* application for *Wear OS* based smartwatches as a software meta artifact.		Evaluation of the design principles implemented in *watchIT* with substantiating qualitative statements of domain experts from the use cases introduced in the first four design science research cycles.

NASCENT DESIGN THEORY

Figure 31. Research design

During extensible literature analysis and a series of workshops that we conducted in summer 2017 with domain experts from a various range of industrial production facilities, we elaborated convenient use cases for the utilization of smartwatches that are representative and differ in their characteristics. We started with a production scenario composed of maintenance and quality assurance (Zenker / Hobert 2019). To design a software-artifact, we applied a research process inspired by the design science research model of Peffers et al. (2007), including (1) problem identification, (2) objectives of a solution, (3) design and development, (4) demonstration and (5) evaluation. With the knowledge gathered during the design and evaluation, we first extended the scope of possible use cases and second transferred the software solution and the underlying principles to the subsequent design cycles. In this way, we traversed four further cycles covering the use cases support (Zenker et al. 2020b), security service (Zenker 2020), and logistics and design and evaluate enhanced and adapted smartwatch-based information systems. As we created several complementary situated implementations representing level one design science contributions (Gregor / Hevner 2013) in the first four design cycles, we generalize our findings in the fifth design cycle to elaborate design principles and develop a level two design science contribution (Gregor / Hevner 2013). Finally, we elaborate on this generalization and propose a nascent design theory according to Gregor / Jones (2007) describing how to design smartwatch-based information systems to support corporate processes and contribute a level three directed design science contribution (Gregor / Hevner 2013).

4.4 Designing SW-based IS Supporting Mobile Employees while Manual Work

This section describes the five design science research cycles, the underlying use cases, and the consecutive deduction of the proposed nascent design theory for the design of smartwatch-based information systems to support mobile employees executing manual work. Each cycle applies a research design inspired by Peffers et al. (2007).

4.4.1 Cycle 1: Production

The production **use case** founds the first design science research cycle, and we formulate the basic set of objectives to design and develop a smartwatch-based IS for the unobtrusive support of mobile employees executing manual work (Zenker / Hobert 2019). The scenario was introduced and discussed with two supervisors of the production of a large-scale biotechnology company. On the one hand, it is composed of machine operators who are responsible for several machines (e.g., mills and stamps) on a shop floor that have to be maintained and equipped during manual work at different locations. On the other hand, there is a quality assurance department where employees periodically measure recently produced components and inform the production employees about possible erosion or corruption of machine tools. We elaborate on two key **problems** that emerge in this setting due to the high mobility and the inability to operate common devices during manual work at the machines: (1) The employees have an uncertainty of the state of their machines and the progress of their colleagues due to spatial separation which necessitates unnecessarily repeated checking. (2) Media disruptions occur varying the representation of information between digital, printed, and written forms. To solve this problem by introducing a smartwatch-based IS, the machine operators should be equipped with smartwatches, and the quality assurance employees should use a stationary desktop PC for better operability. For a generalization to a broad range of scenarios, we formulate the utilization and assignment of smartwatches for mobile employees and a backend for stationary employees in Table 13 as **requirements** (FMR_{Pro1}, FMR_{Pro2}, and FMR_{Pro3}). The smartwatch should display machine information and the status of quality assurance (FMR_{Pro4}) with unobstructive and immediate notifications (FMR_{Pro5}). For a good collaboration, the tasks should be acknowledged (FMR_{Pro6}), and options for the next process step should be provided (FMR$_{\text{Pro7}}$). To improve the corporate processes, statistics (e.g., highlighting machine failures over time) should be provided in the backend (FMR$_{\text{Pro8}}$). The quality assurance employees should create and manage the request for components being measured (FMR$_{\text{Pro9}}$). To enable the smartwatch to provide possible options to conclude a task, a workflow builder is required to implement workflows without the requirement of programming skills defining a sequence of tasks (FMR$_{\text{Pro10}}$). Administrators should assign devices and organize workplace groups, which necessitate a role system (FMR$_{\text{Pro11}}$).

Besides the functionality, according to the domain experts, it is essential to respect the employees' privacy, provide an appropriate battery life of at least an 8-hour shift, robustness to impacts, acids, and oil of the smartwatch, and protection of sensitive corporate information during the transmission (NMR$_{\text{Pro1}}$, NMR$_{\text{Pro2}}$, NMR$_{\text{Pro3}}$, and NMR$_{\text{Pr4}}$).

<table>
<tr><th colspan="4">FUNCTIONAL META-REQUIREMENTS</th></tr>
<tr><td colspan="4">FMR$_{\text{Pro1}}$: Provide user interface for mobile employees that can be operated hands-free and incidental</td></tr>
<tr><td colspan="4">FMR$_{\text{Pro2}}$: Provide user interface for non-mobile employees allowing a holistic overview</td></tr>
<tr><td colspan="4">FMR$_{\text{Pro3}}$: Assign devices to workplaces and aggregate them into functional groups</td></tr>
<tr><td rowspan="4"><i>smartwatch</i></td><td>FMR$_{\text{Pro4}}$: Display activities and tasks with corresponding information associated with the workplace indicating priorities and dues</td><td rowspan="4"><i>backend</i></td><td>FMR$_{\text{Pro8}}$: Provide comprehensive workflow statistics</td></tr>
<tr><td>FMR$_{\text{Pro5}}$: Receive immediate task notifications unobstructively and quietly</td><td>FMR$_{\text{Pro9}}$: Manage activities and tasks with a holistic overview</td></tr>
<tr><td>FMR$_{\text{Pro6}}$: Send immediate acknowledgments hands-free to accept or reject a task</td><td>FMR$_{\text{Pro10}}$: Manage workflows in an intuitive way without the requirement of programming skills</td></tr>
<tr><td>FMR$_{\text{Pro7}}$: Display categorized options to conclude a task within an activity according to the workflow, including the corresponding workplace</td><td>FMR$_{\text{Pro11}}$: Allow access to administrative functions regulated with a role system</td></tr>
<tr><th colspan="4">NON-FUNCTIONAL REQUIREMENTS</th></tr>
<tr><td colspan="4">NMR$_{\text{Pro1}}$: No acquisition and storage of employee-related information</td></tr>
<tr><td colspan="4">NMR$_{\text{Pro2}}$: Appropriate life of battery lasting at least a shift</td></tr>
<tr><td colspan="4">NMR$_{\text{Pro3}}$: Protection against environmental influences like impacts, water, oil, acid, and electrostatic discharge</td></tr>
<tr><td colspan="4">NMR$_{\text{Pro4}}$: Encryption of sensitive corporate data during the transmission and on the devices</td></tr>
</table>

Table 13. Meta-requirements emerged during design cycle 1 within the production scenario

We designed and implemented the smartwatch-based IS *smartActivity* that incorporates the listed requirements. During an additional focus interview, including the demonstration of the software with a supervisor and a manager of a large-scale production workshop, we conducted an **evaluation** of the requirements listed in Table 13. In this way, we confirmed the utility of smartwatch-based IS in the production use case. We deviated design aspects for the architecture, organization, information exchange, collaboration, workflow guidance, and privacy.

4.4.2 Cycle 2: Support

In the second design science research cycle, we addressed the **use case** of support described in detail by Zenker et al. (2020b). We analyzed the two scenarios that emerged in practice: (1) The student IT-infrastructure support team solves hard- and software-related issues and maintains the public desktop workplaces, computer pools, and printers for students. (2) The lecture hall technology team reacts to tickets related to lecturers' issues with smartboards, projectors, microphones, cameras, and PC systems during their lectures. As **problems**, the employees of these teams are highly spatially separated and spread over the whole university but have to collaborate and execute manual work in particular during maintenance that also has to be documented. Continuative of the knowledge and **requirements** of the previous design cycle, the employees requested to forward tasks to a colleague whenever they are busy or do not have enough experience to solve a problem as formulated in $\mathrm{FMR}_{\mathrm{Sup1}}$ (see Table 14). Besides, the existing ticket system of the university should be integrated. At the meta-level, we formulated $\mathrm{FMR}_{\mathrm{Sup2}}$ to extend this request to a broad range of similar scenarios. Finally, a simple way is necessitated to create tasks for a vast computer pool site. For that, we include functionality to create tasks in a batch process ($\mathrm{FMR}_{\mathrm{Sup3}}$).

FUNCTIONAL META-REQUIREMENTS			
smartwatch	**$\mathrm{FMR}_{\mathrm{Sup1}}$:** Forward assigned tasks to other workplaces	*backend*	**$\mathrm{FMR}_{\mathrm{Sup2}}$:** Provide an easy to use and well-documented interface for machines with low computing capabilities or paired systems
			$\mathrm{FMR}_{\mathrm{Sup3}}$: Setup recurring activities and allow to create complex task structures

Table 14. Additional Meta-requirements of design cycle 2 within the support scenarios

To implement a software solution for this particular use case, we design and develop the smartwatch-based information system *supportWatch* by extending the software-artifact from cycle 1. By demonstrating our approach to 22 domain experts, including the three team leaders, we conduct an **evaluation** based on qualitative and quantitative questionnaires and focus interviews with participants of a field study of practical utilization of the system over several days. We could evaluate the requirements and elaborate on enabling and inhibiting factors for the use of smartwatch-based information systems. We refined the design aspects of architecture, organization, and collaboration.

4.4.3 Cycle 3: Security Service

A security service **use case** is the target of investigation in the third design science research cycle to intensify the knowledge about smartwatch-based IS for the support of employees executing manual work even more (Zenker 2020). Security service employees are spatially spread over a vast area and move around, which impedes agreements. As they have to quickly exchange information in hazardous situations like arresting a resisting person, they are strongly limited by hand-operated devices like smartphones. The analyzed scenario is composed of the **problems** of an unobtrusive collaboration of security guards and a central security supervisor who coordinates the tasks, the digital support of security patrols including a defined sequence of checkpoints without the need to carry and retrieve a device, and the protection of employees who often work alone. Extending the knowledge of the first two design cycles, we interviewed a security supervisor responsible for the security service at a large-scale university. In addition to the functionalities listed before, the scenario necessitates several **requirements** noted in Table 15. First, security employees like to have direct communication without retrieving and holding a smartphone (FMR$_{Sec1}$). To address the problem of a lone-working-protection and to support new employees who do not know the locations of the checkpoints on defined routes, the smartwatch should record position information that can guide employees on their way to the next destination, and the security supervisor can track employees in case of an emergency call (FMR$_{Sec2}$, FMR$_{Sec5}$, and FMR$_{Sec5}$). According to less obstructive documentation of presence at a checkpoint, we utilize the smartwatches' ability to recognize NFC tags that can be registered and associated with a particular location (FMR$_{Sec3}$ and FMR$_{Sec7}$). Furthermore, documentation of the issue and return of equipment can be enabled by attaching and scanning a tag. Finally, we respect the request to trigger emergency calls with an immediate motion gesture. On a generalized level, we allowed the system to define and sense such motion patterns to trigger tasks (FMR$_{Sec4}$ and FMR$_{Sec8}$).

FUNCTIONAL META-REQUIREMENTS			
smartwatch	**FMR$_{Sec1}$:** Send text or voice messages to another workplace and provide push-to-talk	*backend*	**FMR$_{Sec5}$:** Visualize locations of employees and progresses
	FMR$_{Sec2}$: Obtain in- and outdoor capable position information to support the next task selection, navigation, and safety		**FMR$_{Sec6}$:** Register locations and aggregate them into groups
	FMR$_{Sec3}$: Recognize contact-free tags to support timekeeping, to trigger tasks, identification, registration of equipment, and to report the presence		**FMR$_{Sec7}$:** Register real-world objects equipped with a tag that is recognizable by sensors
	FMR$_{Sec4}$: Sense motion gestures as well as sensor patterns for interaction and the release of events		**FMR$_{Sec8}$:** Register and train motion gestures and sensor patterns

Table 15. Additional meta-requirements of design cycle 3 within the security service scenario

We implemented the requirements in the situated software-artifact *smartSecurity* and demonstrated our concept to 16 security service employees, including supervisors and managers of a large-scale university, during several presentations. In an **evaluation,** including qualitative and quantitative questionnaires, we reviewed our system. The participants indicated a normalized score of 0.83 (1 is the highest and 0 lowest agreement) for the utility of hands-free operability, 0.86 for the ubiquitous exchange of information, and 0.91 for the mobility aspects. The participants are highly interested in replacing their extant smartphone-based system with a smartwatch-based IS. We refined the design aspects of information, collaboration and added aspects of context-awareness, which are also applicable for the previous scenarios.

4.4.4 Cycle 4: Logistics

The design science research cycle 4 addresses a **use case** within the domain of logistics. Since employees working in a warehouse have to unload trucks, move goods through the warehouse, sort and store packages, and again load trucks, they are highly mobile and execute manual work. There is established hardware like handheld scanners to support warehouse employees to identify goods (Nair et al. 2018). On the one hand, employees have to interrupt their manual work to operate such devices, and on the other hand, no information exchange for collaboration is provided.

During a preliminary qualitative and quantitative questionnaire study with five domain experts of the management and five domain experts of the operating division, we identified potential scenarios for utilizing smartwatches: picking, loading, storage, communication, and task assignment. We implemented the enumerated requirements and configured the *smartActivity* software accordingly. In addition to the already incorporated objectives of the smartwatch-based system, the domain experts outline the **problem** of integrating foreign employees, who speak different languages, and have difficulties communicating with their colleagues. As noted in Table 16, we added the **requirement** FMR_{Log1} to provide a translation of the user interface and multi-language support for the tasks within workflows. Another mentioned aspect is improved privacy by deactivating the smartwatch's functionalities beyond working hours (FMR_{Log2}).

FUNCTIONAL META-REQUIREMENTS
FMR_{Log1}: Support multilingualism
NON-FUNCTIONAL META-REQUIREMENTS
NMR_{Log1}: Execution of all features only in the corporate context

Table 16. Additional meta-requirements of design cycle 3 within the security service scenario

We demonstrated the software-artifact in 16 workshops during September 2020 to 38 employees of a large-scale logistics company with several warehouses at different locations. The participants work in incoming goods, outgoing goods, and management departments and range from loaders and group leaders to managers. During an **evaluation**, including qualitative and quantitative questionnaires, they assessed the utility of multilingualism with 64 %, task assignment with 62 %, and collaboration with 52

% in the presented concept and software. Besides the confirmation of the previous requirements, they liked the idea to use smartwatches during their daily work (applicable for 50 % of the current processes) and express little doubts about possible surveillance. Hence, we refined the design aspects of collaboration and privacy.

4.4.5 Cycle 5: Design and Implementation of *watchIT*

In this section, we assemble the gathered design knowledge from the previous four design science research cycles since saturation of design knowledge is reached, including full coverage of the smartwatch characteristics and the absence of new use cases that exhibit substantially different characteristics and requirements during the empirical studies. For that, we present the generalization of the problem space as well as the design and implementation of the *watchIT* meta software artifact. We traverse a design science research methodology inspired by Peffers et al. (2007) and conclude this section with a nascent design theory following the framework of Gregor / Jones (2007).

4.4.5.1 Problem Identification

As described in the previous section, the various scenarios of the design science research cycles have individual characteristics and necessitate a broad range of demands. We utilize the inductive strategy for design science research described by Iivari (2015), addressed specific problems by building concrete artifacts during the first four cycles, and generalize the solution concept to cover a class of problems. Figure 32 illustrates the process and the context of the elaborated problem class.

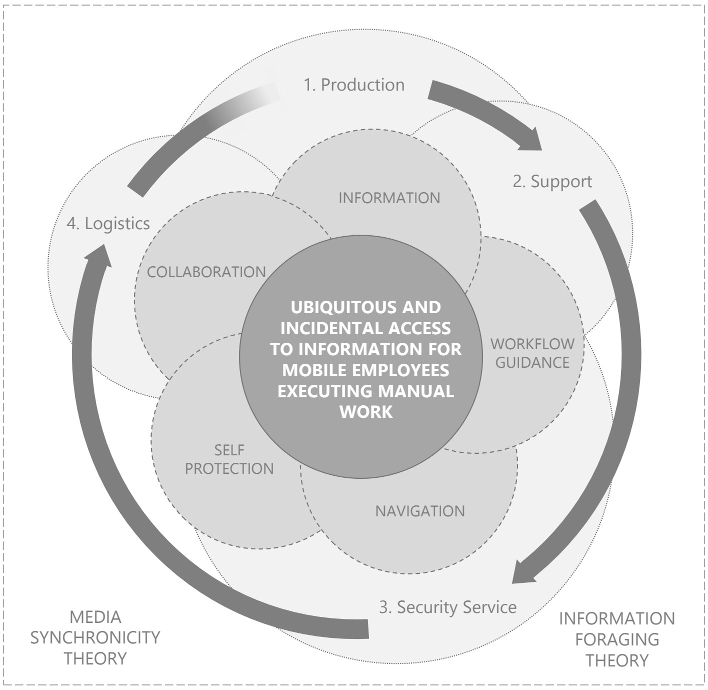


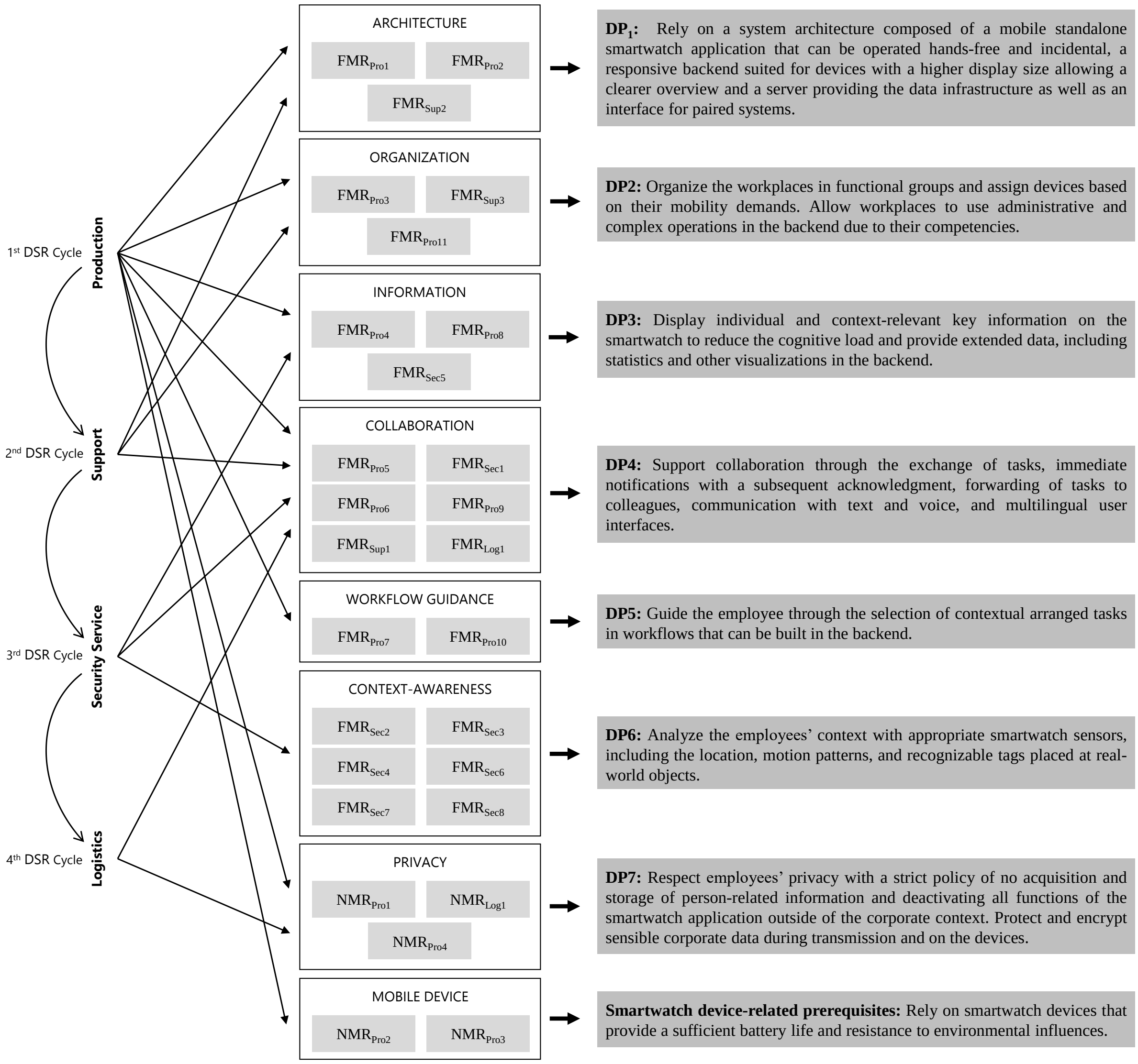
Figure 32. Abstraction of the problems emerged in the scenarios of the four design cycles

The outer circle depicts the realized design science research cycles and indicates the problems that emerged in each associated scenario composing the inner crown. (1) In the production scenario, the collaboration of machine operators and the quality assurance department is characterized by repeating and partially unnecessary footpaths and slow exchange of printed information. Spatial separation, a lacking view of all assigned machines, and noise impede machine operators from directly and efficiently obtain information about possible defects and occurrences. Process information and contact persons are listed at a central office in a written form and cannot be accessed immediately for quick workflow guidance. (2) In the support scenario, the large spatial separation of employees and the information about new tickets and tasks are identified as a critical problem. Also, employees had to use mobile devices like smartphones and laptops that interrupt their maintenance and documentation process without any guidance on what to do next and checking whether everything has been completed to the full extent. (3) Also, security employees need to be guided incidental and silently through their routes checking, for example, the doors of facilities. New employees need much time and effort to learn the extensible processes that can also be randomized to become less predictable. Furthermore, it is circuitous and burdensome for security employees to use, for example, smartphones or maps to find their desired locations. Since, in this case, they have to work alone a lot of the time, there is no reasonable hard- and software solution to detect incidents and dangerous situations and call reinforcement hands-free while, for example, arresting someone. Hence, self-protection is a current problem. (4) In the logistics scenario, collaboration is the focus of attention. Multiple team leaders assign tasks, e.g., loading a truck or stocking goods, to the employees who have to handle heavy packets with their hands. Particularly in this sector, language problems between the employees are typical that complicate the understanding and cooperation. (5) While analyzing and assembling the problems, we deduce the underlying and central problem that ubiquitously and incidentally access to information for mobile employees executing manual work is not reasonably possible with traditional hardware and software.

This problem that emerged in practice can also be found in the research domain and is well known in theory, providing an established foundation illustrated as the outer box in Figure 32. On the one hand, the Information Foraging Theory abstractly describes that the search for information is associated with costs (Pirolli / Card 1999). According to Pirolli / Card (1999), humans tend to obtain as much relevant information as possible. For that, they have to adapt their search strategy to maximize the value of the information (e.g., the usefulness of the information) at the same cost (e.g., search time). Fragmentation of information often impedes the search for information since the required information cannot be accessed from one source entirely, and the aggregation of information patches necessitates additional processing (Pirolli / Card 1999). To improve the information search despite different information fragments, the search environment can be customized trough (1) reducing the effort of searching for information with links, (2) improving the perception so that the searcher can find information better, and (3) supporting the search for information with an information system (Fleming et al. 2013). Transferred to the problem of incidentally supporting employees executing manual work in corporate workflows, gathering information causes additional costs since current work has to be interrupted to operate a mobile device (e.g., a smartphone), or the employee has to move to another location. According to the theory described, a smartwatch-based information system can be utilized to link the individual information sources with each other and to provide an aggregated user interface. In this way, a reduction in the costs of the information search is possible. On the other hand, the Media Synchronicity Theory targets communication processes besides the richness of information and its relation to the task to be performed as introduced in the underlying Media Richness Theory (Dennis / Valacich 1999; Dennis et al. 2008). Media synchronicity describes the extent to which several individuals work simultaneously on joint activities and combines the factors of media characteristics, task function, and communication processes. Depending on the respective expressions of the properties, a suitable selection of media to be used and their synchronicity have to be chosen. Within the given problem of incidentally supporting employees executing manual work in corporate workflows, there are both: (1) convergent processes that condense information, resolve ambiguities, and require high synchronicity (e.g., the exchange of tasks during collaboration or using voice notifications), and (2) divergent processes that transfer and distribute information to reduce uncertainties and require low synchronicity (e.g., informing machine operators about failures, or alerting security service colleagues in case of an incident). Hence, a combination of media offering different degrees of media synchronicity is necessitated. Smartwatches can rely on static information shown on the display, communication is possible through touch and hardware buttons, haptic vibrations can inform about incoming messages, and voice communication can be established with the integrated speaker and microphone. Furthermore, various sensors support implicit communication, e.g., using motion gestures and utilizing the device localization.

4.4.5.2 Objectives of the Solution

Considering the previously defined problem, we gathered all meta requirements that emerged in the scenarios of the previous design science research cycles. To bring the meta requirements to the same abstraction level as the problem, we categorize the meta requirements into functional groups and elaborate design principles based on them. Figure 33 illustrates the process from the originating scenarios examined during the cycles to the categorization of the meta requirements and finally to the design principles representing the objectives of the solution to the problem class. Even though we accentuated the relationship of merely a single scenario to a group of meta requirements, this implies the first occurrence of the corresponding group and the other cycles refined details or confirmed the purpose.



DP$_1$: Rely on a system architecture composed of a mobile standalone smartwatch application that can be operated hands-free and incidental, a responsive backend suited for devices with a higher display size allowing a clearer overview and a server providing the data infrastructure as well as an interface for paired systems.

DP2: Organize the workplaces in functional groups and assign devices based on their mobility demands. Allow workplaces to use administrative and complex operations in the backend due to their competencies.

DP3: Display individual and context-relevant key information on the smartwatch to reduce the cognitive load and provide extended data, including statistics and other visualizations in the backend.

DP4: Support collaboration through the exchange of tasks, immediate notifications with a subsequent acknowledgment, forwarding of tasks to colleagues, communication with text and voice, and multilingual user interfaces.

DP5: Guide the employee through the selection of contextual arranged tasks in workflows that can be built in the backend.

DP6: Analyze the employees' context with appropriate smartwatch sensors, including the location, motion patterns, and recognizable tags placed at real-world objects.

DP7: Respect employees' privacy with a strict policy of no acquisition and storage of person-related information and deactivating all functions of the smartwatch application outside of the corporate context. Protect and encrypt sensible corporate data during transmission and on the devices.

Smartwatch device-related prerequisites: Rely on smartwatch devices that provide a sufficient battery life and resistance to environmental influences.

Figure 33. Transfer from design cycles to groups of requirements and design principles

The first group of meta requirements covers aspects according to the information system's architecture. As already deduced in the production scenario (DSR Cycle 1), the IS addresses two groups of employees: (1) mobile employees who execute manual work and (2) stationary or partial mobile employees. To ensure that the device characteristics are used effectively, we propose to use a standalone smartwatch application overcoming dependencies of other devices (e.g., smartphones) for the mobile employees who can benefit from the unique mobile qualities (FMR$_{Pro1}$). It can be operated hands-free and incidental but offers a limited capability to display information due to its small form factor and display size. Stationary employees who are not reliant on their hands during their work (e.g., team leaders) instead profit from larger display size and a holistic overview (FMR$_{Pro1}$). Finally, a server should provide the system's infrastructure and allow communication with other machines or systems using an interface (FMR_{Sup2}) predominantly motivated in the support scenario (DSR Cycle 2). Combined, these factors describe the architecture of the IS and produce DP_1.

The second group of meta requirements unifies organizational aspects of the IS to DP_2. As also deduced from the production scenario (DSR Cycle 1), companies should equip the employees with adequate devices based on the individual demands on mobility and assign them to workplaces organized in functional groups, e.g., departments (FMR_{Pro3}). Workplaces with respective competencies have access to administrative functions in the backend (FMR_{Pro11}). Also, tickets and scheduled maintenance from the support scenario (DSR Cycle 2) necessitate the backend to handle recurring and complex tasks (FMR_{Sup3}).

DP_3 is composed of requirements covering information within the IS and indicates that due to the small form factor, only context relevant essential information should be displayed on the smartwatch, and the holistic data is visualized in the backend. In the production scenario (DSR Cycle 1), we identified that for the smartwatch, especially information about current activities and tasks, including priorities and dues, should be displayed (FMR_{Pro4}). The backend should above provide detailed process statistics (FMR_{Pro8}). By dint of the security service scenario (DSR Cycle 3), the localization of the different workplaces and the progress should be visualized in the backend (FMR_{Sec5}).

Next, there is a group of meta requirements addressing the collaboration. The basic functionality is already elaborated in the production scenario (DSR Cycle 1). Mobile workplaces should be immediately notified of incoming tasks in an unobstructive and quiet way (FMR_{Pro5}). Furthermore, it should be possible to acknowledge these notifications to signal the colleagues an acceptance or rejection of the task (FMR_{Pro6}). The backend should provide functions to start and manage activities and tasks with a holistic overview (FMR_{Pro9}). These demands are refined in the subsequent design science research cycles. In the support scenario (DSR Cycle 2), it is required to forward assigned tasks to other workplaces in case of an overload or reorganization (FMR_{Sup1}). The security service scenario (DSR Cycle 3) necessitates the requirement to provide an individual and direct flow of information sending text or voice-based messages and to provide push-to-talk (FMR_{Sec1}). Finally, within the logistics scenario (DSR Cycle 4), it is essential to support different languages in the user interface, and the workflow steps since foreign employees have fewer problems of understanding (FMR_{Log1}). Summarized in DP_4, immediate notifications with a subsequent acknowledgment, forwarding of tasks to colleagues, communication with text and voice, and a multilingual user interface are required to support the collaboration of employees and departments.

The workflow guidance is another primary group of meta requirements that emerged in the production scenario (DSR Cycle 1) and is confirmed in every subsequent cycle. It establishes the design principle DP_5. In the backend, workflows should be managed and compiled intuitively without the premise of having programming skills (FMR_{Pro7}). According to these predefined templates, workplaces can be guided by providing the next steps and categorized options to conclude a task (FMR_{Pro10}).

Since smartwatches are worn directly at the employee's body, a unique characteristic is the availability of sensor information that can be utilized to deduce the employees' context composing DP_{6}. As recently as the security service scenario (DSR Cycle 3) generated demands to benefit from the employees' context, but this concept can be seamlessly transferred to all other scenarios. First, the in- and outdoor position information of the smartwatch can be used to support the next task selection, navigation, and safety (FMR_{Sec2}). In the backend, locations to interact with should be managed (FMR_{Sec6}). Second, tags placed on real-world objects should be recognized by the smartwatch to support timekeeping, to trigger tasks, identification, registration of equipment, and to report presence (FMR_{Sec3}). The tags should be registered and managed in the backend (FMR_{Sec7}). Finally, motion gestures and body sensor patterns should be used for interaction and the release of events (FMR_{Sec4}). The required patterns can be managed and trained in the backend (FMR_{Sec8}).

Another critical success factor that emerged in the production scenario (DSR Cycle 1) and was accentuated during all studies is the high demand for privacy building the DP_{7}. To prevent surveillance and abuse of personal data, the storage and acquisition of employee-related data should be strictly prevented (NMR_{Pro1}). Since smartwatches can also be worn in the private context, it has to be possible to limit the execution of the functionalities to the corporate context (NMR_{Log1}). Besides, sensible corporate data should be protected and encrypted during transmission and on the devices (NMR_{Pro4}).

Finally, there is a group on non-functional meta requirements that define characteristics of the mobile device. On the one hand, the smartwatch device should last at least a complete shift without charging (NMR_{Pro2}), and on the other hand, it should be protected against environmental influences like impacts, water, oil, acid, and electronic discharge (NMR_{Pro3}) already identified in the production scenario (DSR Cycle 1). Since these factors do not directly influence the design of a smartwatch-based IS, we declare them a smartwatch device-related prerequisite.

4.4.5.3 Design and Development

To meet the specified objectives in the form of the seven design principles and the underlying meta requirements in a smartwatch-based information system, we design and develop the software meta-artifact *watchIT*. As depicted in Figure 34, it is composed of three components: (1) a standalone native *Wear OS* smartwatch application, (2) a web backend, which can be operated using a browser on a desktop or mobile device, and (3) a server, which offers the system's infrastructure including the database and interfaces. In this way, mobile employees executing manual work can be equipped with smartwatches offering hands-free and incidental operation. Stationary employees can use the web-based backend on smartphones or desktop terminals, benefiting from the larger screen size allowing a more precise overview. Other systems, e.g., cyber-physical systems (Lee 2008), can interact using the interfaces (DP_{1}). An encrypted enterprise wireless network connects all components quickly, reliable, and secure (DP_{7}). As confidential data like machine information or employees' locations is processed, only internal data connections and self-operated hardware components are used, and external devices are excluded to prohibit any disturbances or influence on work processes. Furthermore, there is full control over the infrastructure as well as the data, and the components of the system do not depend on the availability and future compatibility of external services.

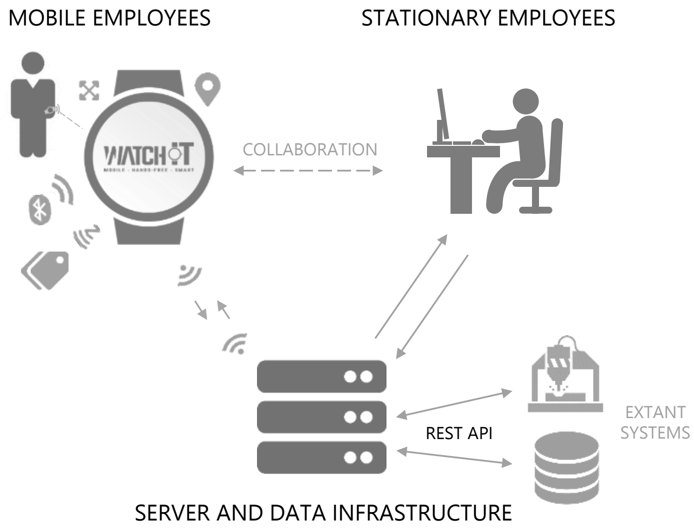
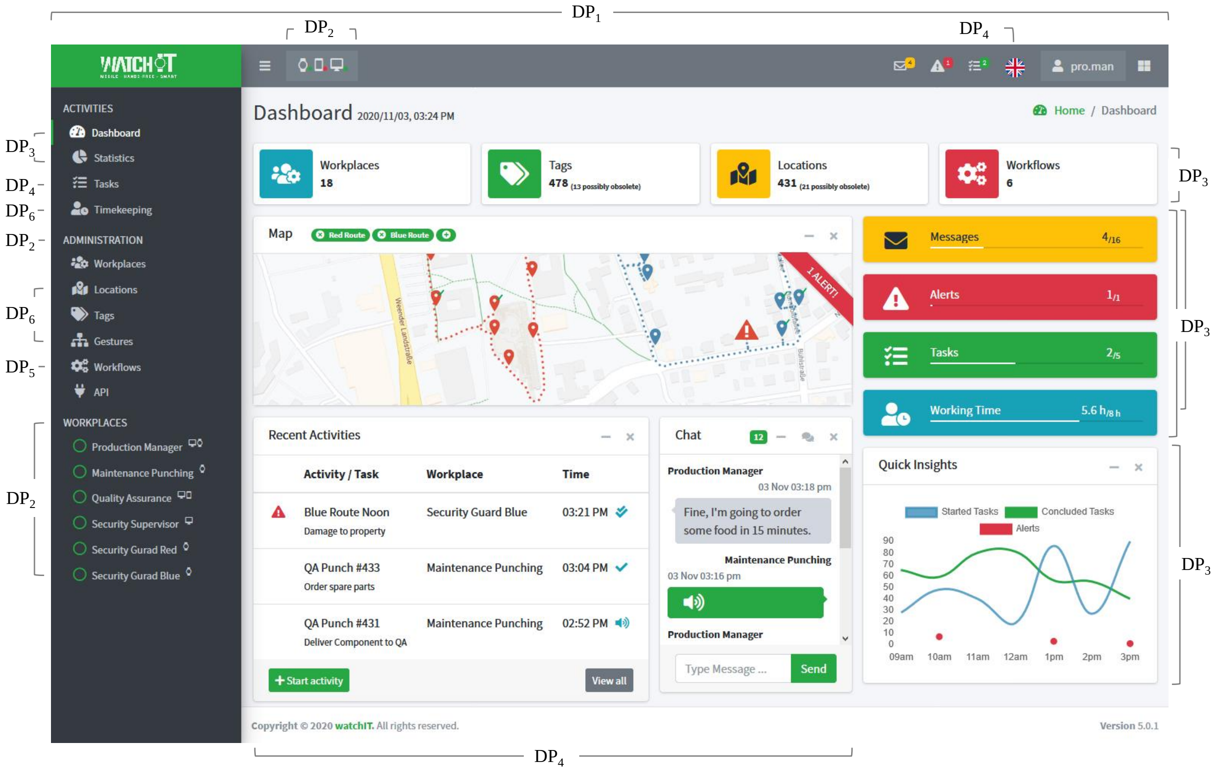


Figure 34. The *watchIT* sytem architecture

We rely on PHP at a Linux operated Apache server to benefit from its abilities related to web applications. In this way, the web-based backend is empowered with modern web technologies like HTML5 and JavaScript and can be responsibly displayed on various devices like smartphones or desktop computers due to a Bootstrap-based layout. For the communication of the server and the smartwatch as well as the backend component, we implemented a push mechanism for immediate information exchange (DP_4) based on a self-hosted *WebSockets* server integrated via *JavaScript* in the backend and *Pusher*-based *Java* implementation in the smartwatch component (Lengstorf / Leggetter 2013; Pociot / van der Herten 2020; Pusher Ltd. 2020). This approach is very effective concerning usability and the number of server requests relieving the infrastructure. Also, a REST interface supporting identification and authentication methods can be utilized to integrate other systems like machines transmitting failures or sensor data as well as existing ticket systems. For data storage, we choose a relational MySQL database. The selected components at the server-side are well known and approved technical approaches to ensure easy applicability in practice.

The **web-based component** is operated through a browser and is the backend of the *watchIT* application (DP_1). It allows employees to manage and supervise all processes on a device with larger screen size, like a desktop PC, tablet, or smartphone, which ensures an adequate overview. A login, including an ID and a password, protects the system from unintentional access (DP_7). *watchIT* comprises a central dashboard that provides access to relevant key information to evaluate the current situation and all further functionalities. A screenshot of the dashboard is shown in Figure 35.



Recent Activities

	Activity / Task	Workplace	Time
⚠	Blue Route Noon Damage to property	Security Guard Blue	03:21 PM ✓
	QA Punch #433 Order spare parts	Maintenance Punching	03:04 PM ✓
	QA Punch #431 Deliver Component to QA	Maintenance Punching	02:52 PM

Chat 12

Production Manager
03 Nov 03:18 pm
Fine, I'm going to order some food in 15 minutes.

Maintenance Punching
03 Nov 03:16 pm

Production Manager

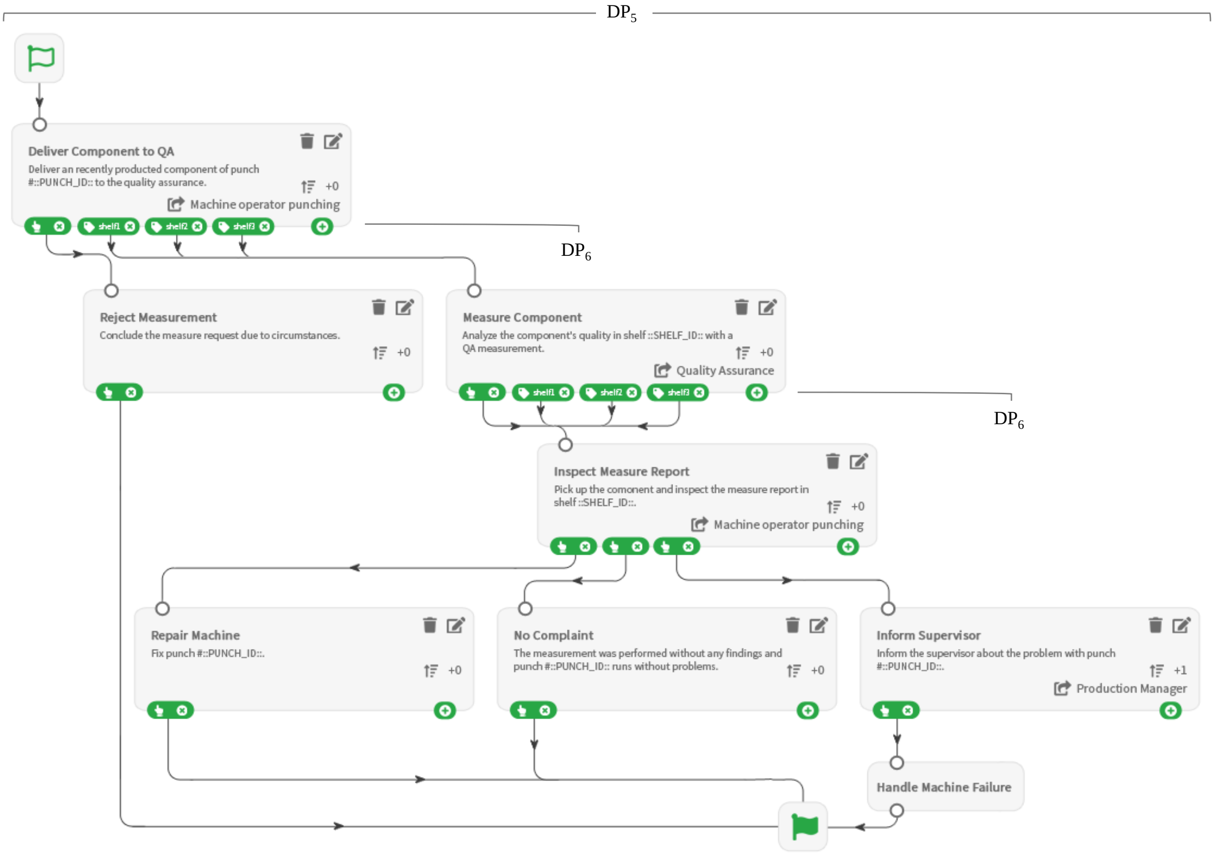
Figure 35. The *watchIT* dashboard of the web-based backend

According to DP7, employees are incorporated with their occupied workplace representing their functional role (e.g., Production Manager) instead of names to avoid tracking person-related data and possible surveillance. Based on the workplace's demands on mobility, employees can use a smartwatch, a smartphone or tablet, and a desktop terminal symbolized on the top panel's left side (DP2). At any time, it is possible to benefit from several device characteristics through the possibility of multi-device operation and synchronization (e.g., a smartwatch can call attention to notifications displayed in the dashboard with vibrations). Implementing DP4, the language of the user interface can be changed to individual preferences. Especially translations of the steps within a workflow are helpful for foreign employees to understand and execute the process clearly. In the dashboard's first row, employees have a quick insight into relevant key figures representing the number of registered workplaces, tags, locations, and workflows (DP3). Hence it is possible to maintain the system's tidiness and to remove obsolete entries. In the second row, there is a map-based representation of locations and routes (DP3). It is not possible to track an employee's location as claimed in DP7 unless an interaction with a tag associated with a particular place or a motion gesture issues the next step. In this particular example, two routes of security guards who have to visit a defined sequence of facilities to check doors and windows and watch for occurrences (e.g., vandalism) are displayed. The system provides insights about the activity's progress and highlights the location of occurrences for a fast reaction. On the right-side panel, critical factors, like the number of unread and received messages, alerts, open tasks, and an indicator for the own current working time, are shown to overlook and assess the situation (DP_3). Below, there is a customizable plot representing process performance and occurrences over time that can be used to identify the weaknesses of the workflow organization and then elaborate on improvements (DP_3). The left panel at the bottom surveys the actual activities and according tasks (DP_4). Important tasks are prioritized and displayed at the top since they have to be considered first. Moreover, the time and acknowledge status is indicated for each task. If a voice message is recorded as a task response, this can be accessed through a media player. On the right-hand side is a panel providing direct chat functionalities (DP_4). The target workplace can be selected, and a text and voice-based chat can be started. Text messages should be preferred from the backend component since smartwatches have weak capabilities for text input due to the small form factor (Chaparro et al. 2015), and a voice message can be used instead. Based on the particular use case requirements, the panels can be arranged to individual needs, and unneeded components can be removed from the dashboard.

The left panel of the web-based backend contains the menu and offers access to the specific functionalities of *watchIT*. First, there is a section providing detailed process statistics (DP_3). On the one hand, the processes can be improved. On the other hand, it can be analyzed whether the existing resources are sufficient to operate efficiently (e.g., an additional employee has to be hired). Respecting DP_7, merely the processes can be analyzed, and due to the aggregated form, no conclusions to individuals are possible. A central functionality of *watchIT* and addressing DP_4 activities with subsequent tasks can be started, assigned, and managed. It is possible to use defined workflows as a template or issue individual tasks. For a holistic overview, all specified workflow tasks can be displayed in an adapted Kanban board (Ohno 1988). For that, the tasks are organized in a table composed of columns according to each workflow step. The activities are assigned to the current workflow step ordered by the priority and maturity. Another functionality implementing DP_6 is timekeeping. For that, we register a central or individual NFC tag ID placed at an appropriate location within the worksite in the system. The employee can sign in and out for work by scanning the tag with the smartwatch, converging the device to a few centimeters to document the individual working times. Besides, the smartwatch's functionalities can automatically be deactivated after the logout until the next login (DP_7). In the next section, several administrative functionalities are only available for authorized workplaces, according to DP_2. This includes the management of the workplaces which have to be created, edited, and deleted. Furthermore, the devices have to be assigned to the workplaces using a unique token, and accounts have to be configured in the backend. The next three menu entries implement various aspects of the sensor-based context-awareness formulated in DP_6. First, locations of the real world can be managed in the backend. On the one hand, the geographical coordinates of the location can be determined on a map and registered in the system. As the smartwatch is equipped with a GPS receiver, the distance to the defined coordinates can be calculated outdoors. On the other hand, we rely on Bluetooth beacons to support indoor localization due to the weak coverage of GPS indoors. For that, also, the location of Bluetooth transmitters is registered that broadcasts a defined ID continuously. According to the signal strength of a Bluetooth beacon sensed by the smartwatch, a distance to the location can be calculated or even triangulated (Chawathe 2009). Each location can be used within the workflows to trigger tasks according to the employee's context according to the location. Second, it is possible to register NFC tags that are small, inconspicuous, easy to install at objects, and cheap. Whenever a smartwatch is close to an NFC tag (a couple of centimeters), the system can issue or conclude context-related tasks. Finally, individual gesture patterns can be recorded with the smartwatch sensors and associated with actions within the workflows. For example, a gesture for an emergency call could be trained, enabling the employee to call for help quickly and without taking a device out of the pocket. Next, there is a section to manage entities that are enabled to use the *watchIT* interface. For security reasons each machine, or system that should communicate with *watchIT* is registered, the access rights can be configured, and a randomly generated token is assigned. The admitted entities can now invoke well-documented links, including all needed parameters due to the implemented HTTP-based REST API to, for example, start an activity concerning machine failures or arriving support tickets. In the opposite direction, it is possible to define a callback-URL to inform the entity, for example, of concluded tasks. According to $DP_{2,}$ at the bottom of the left side menu panel, there is a list of currently available workstations. It indicates what kind of device each workplace is using, and the links can be used to apprehend the current workplace tasks.

DP_5 formulates an essential idea to enable process support with smartwatches due to the problem of a small form factor and weak capabilities for text input: predefined workflows. Several options have to be defined for straightforward and incidental selection to utilize the unique characteristics of smartwatch devices. Figure 36 shows a screenshot of the *watchIT* workflow builder with a sample quality assurance process from the production scenario (DSR Cycle 1).

According to DP5, we provide a user interface based on drag and drop by implementing the workflow builder. In this way, an individual workflow can be assembled between the start (empty flag at the top) and the end (filled flag at the bottom). Steps can be added, edited, removed, and connected arbitrarily, which then are traversed while executing an activity. An expressive name and a description identify each task. It can be chosen if the priority of the activity increases with the respective task, decreases, or stays the same. Concerning DP_6 locations, tags and gestures previously registered in the backend can be integrated. For example, the task for a machine operator to deliver a currently produced component to the quality assurance can be concluded by scanning a particular NFC tag at the quality assurance rack, automatically registering in which shelf the quality assurance employee subsequently has to pick up the order. Locations can be used in the same manner and are triggered whenever an employee enters a defined distance around a particular position. Besides, gestures are especially convenient to trigger activities like emergency calls. It is also possible to incorporate already defined workflows in an actual workflow to modularize the processes. Using a special syntax, variables can be declared and passed through the tasks that can be defined whenever an activity with a particular workflow is started (e.g., indicating a machine or component ID). In this way, complex and concurrent workflows can be customized.


Deliver Component to QA

Deliver an recently producted component of punch #::PUNCH_ID:: to the quality assurance.

Reject Measurement

Conclude the measure request due to circumstances.

Measure Component

Analyze the component's quality in shelf ::SHELF_ID:: with a QA measurement.

Inspect Measure Report

Pick up the comonent and inspect the measure report in shelf ::SHELF_ID::.

Repair Machine

Fix punch #::PUNCH_ID::.

No Complaint

The measurement was performed without any findings and punch #::PUNCH_ID:: runs without problems.

Inform Supervisor

Inform the supervisor about the problem with punch #::PUNCH_ID::.

Handle Machine Failure

Figure 36. The *watchIT* workflow builder with a quality assurance scenario

Figure 37 shows screenshots of the **smartwatch component** of *watchIT*. In this study, we rely on *Wear OS* developed by *Google* since it supports various smartwatch models of different manufacturers, and it is free to use. Most of the supported devices are circular and exhibit the characteristical touchscreen complemented by hardware buttons or a digital crown.

Figure 37. The smartwatch based component of *watchIT* for *Wear OS* operated smartwatches

The first screenshot in Figure 37 (1) shows the loading screen of the *watchIT* smartwatch application. The process indicator at the outer border of the display suggests that the application is launching and is connecting to the server. In the case of first access, the system negotiates a unique token and registers the device in the backend to associate it with a workplace. A menu can be retrieved with a swipe gesture from top to bottom, providing several settings and the device token that identifies the smartwatch and can be found in the backend.

After the starting procedure is completed, the task overview is shown (Figure 37 (2)) according to DP_5. The workplace-related tasks are arranged by priority and maturity. The list can be swiped up and down with a finger gesture. At the bottom, a connection indicator shows the connection's strength and the server's unavailability whenever the wireless network coverage is too weak.

As soon as a task is associated with the workplace, a notification pops up, as shown in Figure 37 (3) implementing DP_6. This notification activates the smartwatch screen in case of energy-saving mode and alerts the employee with vibrations at the wrist. According to the task priority, the icon changes, and the vibration's pattern and intensity are adjusted. It is possible to accept and acknowledge, reject, or postpone the incoming task via the appropriate buttons.

Figure 37 (4) shows the detail page of a task. The inner-circle contains the name of the activity and task, the originator, and the time of issue (DP_3). The outer circle represents the collaboration and workflow guidance aspects offering the next possible steps according to the process tree assembled in the workflow builder and the possibility to respond with a voice message (DP_4 and DP_5). The list of options can be scrolled through with a circular swipe gesture. Due to the Cognitive Load Theory (Sweller et al. 1998), we reduce the number of possible options using a mixed-method approach to diminish the complexity. First, we allow to cluster the options to hierarchical groups that can be traversed in a tree structure from the general label to the substantial tasks as leaves (e.g., a security service employee likes to report an occurrence, a possible sequence could be: occurrence at the location, damage at the building, damage at the door, lock cracked). Second, we use automatic prioritization and organization of options with a machine learning approach. The system trains the underlying support vector machine model relying on the Java-based version of the *LIBSVM* library by Chang / Lin (2011) using an input vector composed of contextual information like time, location, or motion patterns and the progress status recorded during the daily use and predicts contextual high relevant options. These options are presented first to the employee who benefits from the fast selection without an excessive search, which reduces costs and improves the search result as postulated in the Information Foraging Theory (Pirolli / Card 1999).

Figure 37 (5) shows the ability of *watchIT* to scan NFC tags implementing DP_6. The ID of each tag is registered in the backend and associated with some describing information. NFC tags in small adhesive stickers or key fobs placed at buildings or equipment to interact with can trigger and conclude activities within workflows. As the tags do not require energy input, they can be recognized and read with the smartwatch at a distance of a few centimeters. Since the tags contain no useful information, they even can be placed in public places, but practice shows that this should be done inconspicuously due to vandalism. For example, security service employees can document their presence at a particular location by scanning placed tags, the issue and return of equipment occupied with tags can be tracked and documented, and an employee can be identified by the system with a personal NFC tag, for example, placed on a work pass.

Another aspect of DP_6 is shown in Figure 37 (6). *watchIT* continuously monitors the acceleration sensors for previously defined motion patterns. In case of an incident or raid, an automatic emergency call can be issued. In the case of false detection, employees are informed visually and tactilely with strong vibrations to stop the process within a defined time. Furthermore, it is possible to trigger a set of activities with defined motion patterns without the operation of the touchscreen. According to that, it is possible to acknowledge an incoming task with a shake gesture quickly or to call reinforcement by stretching the arm into the air and turning the wrist three times.

Figure 37 (7) illustrates the ability of *watchIT* to support the navigation of employees. The system relies on GPS information outdoors and Bluetooth beacon distance triangulation indoors (Chawathe 2009). Besides possible proximity warnings for explosion protection in coating rooms, a distance and direction to the target can help mostly inexperienced employees to find their next destination or guide them to the nearest rescue point in case of an emergency.

Figure 37 (8) shows the authentication of an employee on the smartwatch. Based on the problem of text input on the small touchscreen, the objective of this identification and authentication method is to provide an incidental operation without the necessity to use both hands, ensure practicability in a various range of work contexts, and to be protected against guessing attacks (Bonneau et al. 2012), shoulder surfing (Tari et al. 2006), smudge attacks (Aviv et al. 2010) and video attacks (Yue et al. 2014). For that, we rely on machine learning and introduce a training phase for password definition. Comparable to the study of Nguyen / Memon (2018) where the user has to tap a password with the second hand on the touchscreen, we enable the user to create an individual shaking gesture composed of an easy to remember (e.g., melodic) sequence of up and down motions of the wrist. Since besides the segments' rhythm, the intensity and acceleration values are also considered and incorporated into the input vector for the support vector machine implemented with the *Java*-based *LIBSVM* framework (Chang / Lin 2011), it is practically impossible to copy a password by observation.

Finally, DP_7 is implemented in the smartwatch application through the encryption of data at the device. Whenever data have to be stored in the file system, information is obfuscated using Advanced Encryption Standard (AES) with a symmetric key generated by the smartwatch application during the initialization phase (Tayde / Siledar 2015). Hence third persons who acquired undesirably a corporate smartwatch device cannot read the files in plaintext.

4.4.5.4 Evaluation

Finally, we conduct an evaluation step according to our research design inspired by Peffers et al. (2007). During this phase, we evaluate the previously elaborated design principles implemented in the *watchIT* artifact by applying the conclusions of the participants of the studies traversed in the first four design science research cycles. Following this stringent logic, this consequently substantiates the designed and developed meta-artifact *watchIT*.

Overall we discovered a low diffusion of smartwatches in the corporate context. None of the involved companies have already utilized smartwatches in their processes. In Table 17, we compare the normalized results of the quantitative evaluations in design science research cycles two, three, and four (cycle one merely is based on qualitative investigations). On the one hand, the participants averaged indicate a high IT affinity of 0.78 on a normalized scale between and including 1 and 0 (highest and lowest agreement). The values for the particular use case fluctuate due to the individual interest in technology, which is expected to be highest at the IT support. On the other hand, we determined that only 16 % of the participating employees within the support use case have already used smartwatches. The average of the experience levels with smartwatches is only 0.45 (correlating with the IT affinity for the individual values of the use cases). Predominantly, the participants know smartwatches from the private domain. Opposite to the so-far low utilization of smartwatches in the corporate context, 62 % of the support employees do not have doubts about integrating smartwatches into their daily work (despite many privacy concerns), and the average score for supporting work with smartwatches is 0.82 while the individual scores are very similar regardless to the previous experience. The overall utility of a smartwatch-based IS was evaluated with a 0.76, and the participants state a 0.71 for the facilitation of their daily work. For both questions, the values of the security service use case are significantly higher. The security service employees liked the idea to gain support through a digital system and indicated a 0.82. The most convincing characteristics of a smartwatch-based IS have been the mobility (0.9), the ubiquity exchange of information (0.85), and the hands-free operation (0.83) that resolve obstructive problems inhibiting a seamless integration of IS into the daily work compared to the extant smartphone-based system that is recently used. The major concerns arose from the aspect of possible surveillance. The average score is 0.39 and exceptionally high for the security service use case where a certain level of monitoring contributes to employee protection. Finally, the participants stated with a score of 0.81 that they are interested in using a smartwatch-based IS in the future.

	Support	**Security Service**	**Logistics**	**Mean**
IT affinity of participants	0.82	0.79	0.73	**0.78**
Experience with smartwatches of participants	0.49	0.48	0.38	**0.45**
Idea to support work with smartwatches	0.81	0.8	0.85	**0.82**
Overall utility of an smartwatch-based IS	0.7	0.83	0.75	**0.76**
Facilitation of the daily work routine	0.62	0.82	0.68	**0.71**
Feeling of surveillance	0.35	0.54	0.28	**0.39**
Interest of participants to use a smartwatch-based IS in the future	0.79	0.87	0.78	**0.81**

Table 17. Comparison of exemplary quantitative evaluation results after normalization

According to the design principles, we gathered representative statements from the participants of the conducted qualitative studies. The domain experts confirm the architecture of the presented information system (DP1), highlighting the advances of smartwatches' unique characteristics. They punctuate the necessity of a backend that complements the smartwatches supporting larger screen sizes. As a core-element, the workflow builder was denominated, which makes it possible to bypass several drawbacks of smartwatches as little space to display information and the unavailability of suitable text input. Finally, they highly value the interfaces for extant systems and the interaction of all components. Table 18 supplies the according exemplary statements while indicating the corresponding domain expert from one of the presented scenarios.

Design Principle 1	
Smartwatch	*“The employee is happy with anything not to have to carry along – smartwatches are very beneficial for that since they are small and lightweight.”* (Sec-Exp$_1$) *“Smartwatches can replace a variety of devices such as radio, mobile phone, and beeper.”* (Sec-Exp$_3$) *“I liked that you wear something on your body that you can’t forget or lose and you always have your hands free”* (Sec-Exp$_3$) *“This is the possibility to automate mobile processes through digitalization using such a small computer that you carry around on your wrist”* (Sup-Exp$_1$)
Backend	*“The backend and especially the idea of the workflow builder resolve practical barriers associated with the device characteristics and make the use of smartwatch feasible.”* (Pro-Exp$_4$)
Interfaces	*“The possibility to have a web interface where I can work reasonably on the computer, to have a smartwatch app that is coordinated with it and work together with the other systems.”* (Sup-Exp$_3$)

Table 18. Statements of the domain experts from practice according to DP$_1$

The organization proposed in our IS design (DP$_2$) is supported by the participants highlighting the arbitrary assignment of devices to workplaces that can be shaped depending on the individual demands on mobility. Besides, the role system and the ability to administrate processes has been perceived very well. The associated statements are listed in Table 19.

Design Principle 2	
Device Assignment	*“I like the approach to have a device and user interface aligned to the individual needs that work together, and I can even use the smartwatch at my desktop workplace to have the vibrations on incoming messages and react with the PC.”* (Pro-Exp$_1$)
Administration	*“Now I see the possibilities that you actually have with such a system. Because with it I can theoretically control employees throughout the factory, distribute orders and so on.”* (Pro-Exp$_4$) *“My principal can see the progress of my work and assign new tasks to me every time.”* (Sup-Exp$_1$)

Table 19. Statements of the domain experts from practice according to DP$_2$

Table 20 summarizes the participants’ statements according to the information aspect of the smartwatch-based IS (DP$_3$). On the one hand, they describe the usefulness of fast and incidental accessible context-relevant key information on the smartwatch. Security service employees evaluated that the smartwatch screen has an appropriate size for the proposed shape of information with 0.63. On the other hand, the participants like the holistic presentation of information in the backend, providing additional value through visualizations and statistics.

Design Principle 3	
Context Relevant Key Information	*"You have a fast and easy accessible overview at the body every time."* (Sec-Exp$_{15}$) *"I extremely liked the fact that you have an up-to-date overview on one screen indicating locations to be checked and who the contact persons are."* (Sec-Exp$_{5}$) *"First I was worried that it might be difficult to operate and tap on the smartwatch since the display is small, but it works relatively well." (Sec-Exp$_{1}$) "Control elements were appropriately dimensioned, and I didn't have to enter any letters or numbers."* (Sec-Exp$_{5}$) *"I do not want my employees to run through the workshop but to receive information directly."* (Pro-Exp$_{2}$)
Statistics and Visualizations	*"Statistics would also help us. Then you can find out what you can do better."* (Pro-Exp$_{2}$) *"We can track the frequency of events and use them for process improvements."* (Sec-Exp$_{3}$)

Table 20. Statements of the domain experts from practice according to DP$_3$

DP$_4$ concerning the collaboration aspects of the smartwatch-based IS is founded on the statements listed in Table 21. The participants like the proposed idea to implement notifications, including haptic feedback that eliminates the necessity to observe a display. Furthermore, communication in the form of the assignment, acknowledgment, and forwarding of tasks is identified as a critical feature. Logistics domain experts evaluate the utility of the collaborative functionalities with 0.83. Ultimately, the ability to provide a multilingual user interface and workflows enable the smartwatch-based IS to establish unequivocal communication between employees who do not speak the same language. Within the logistics workflow, the utility of multilingualism is evaluated with 0.85.

Design Principle 4	
Notification	*"The vibration is a pleasant way to be informed about incoming tasks even in loud environments without the need to watch the display all the time."* (Sup-Exp$_{5}$) *"I visualize the task acknowledgment to the quality assurance employee, and he knows in case that the worker is currently busy, but it is being done later."* (Pro-Exp$_{1}$)
Communication	*"Smartwatches can accelerate workflows and make communication easier."* (Sup-Exp$_{11}$) *"They provide fast reachability in case of critical tasks."* (Sup-Exp$_{15}$) *"Translations enable foreign employees to understand our workflows with less training requirements even with a high fluctuation."* (Log-Exp$_{21}$)

Table 21. Statements of the domain experts from practice according to DP$_4$

DP$_5$ describes the workflow guidance, and the definitive statements are listed in Table 22. On the one hand, participants emphasize that in particular new employees can benefit from the guidance, and the incorporation is faster and requires less effort. Since the IS can provide clear decision support based on priorities, dues, and maturities, employees' cognitive load decreases while they can work more efficiently.

Design Principle 5	
Workflow Guidance	*“The structure of the workflows helps new employees to learn our processes faster, and they avoid a lot of uncertainties and mistakes.”* (Log-Exp_{13}) *“The employee is more guided, which is exactly what I want while it is not so complex, it is easy to learn, especially for the young people who grew up with technical devices like that.”* (Pro-Exp_4)

Table 22. Statements of the domain experts from practice according to DP_5

A unique characteristic of smartwatches is obtaining information from various sensors that can be utilized for a context-awareness (DP_6). In the proposed design, we formulated three possible forms of context-awareness of smartwatches. The in- and outdoor localization can be used for navigation and guide employees in case of emergencies. Motion patterns of the employees’ wrists can be detected and utilized to trigger tasks. Finally, tags placed on real-world objects can be used for interaction and documentation of relevant occurrences. Table 23 lists the according statements of the domain experts.

Design Principle 6	
Localization	*“For new employees, it is much easier to learn our routes and locations of the checkpoints with less apprenticeship.”* (Sec-Exp_{12}) *“In case of a fire alarm employees are guided to the next rescue zone preventing panic”* (Log-Exp_{18})
Motion Patterns	*“Sending an acknowledge by shaking my wrist for me is the quickest possibility to react on incoming tasks.”* (Sec-Exp_2) *“To Request reinforcement without being seen or anybody getting worried is a big advantage over smartphones.”* (Sec-Exp_{10})
Tags	*“Scanning the tags at the checkpoints saves me time, and I no longer have to take a device out of my pocket every time.”* (Sec-Exp_5) *“An automatic digital documentation of equipment issue decreases our written effort dramatically.”* (Sec-Exp_3)

Table 23. Statements of the domain experts from practice according to DP_6

As established in practice, privacy and data security are critical factors for the success of a smartwatch-based IS. Security service employees evaluated the feeling of surveillance with 0.53. Table 24 provides even more insights into the underlying problem. Due to the characteristic of smartwatches that they are directly connected to the employees’ body, it is possible to track much person-related information. It is essential to prohibit the abuse of such data through a strict limitation of data recording that is unnecessary for work processes and a functional view on workplaces. Besides arrangements in the design of a smartwatch-based IS, it may be necessary to negotiate agreements with the workers’ council and integrate employees in the early stages of the introduction process. Furthermore, sensible data have to be protected what necessitates an encrypted exchange and storage of information.

Design Principle 7	
Person-related data	*“The smartwatch assists my daily work, but it should not track me, and I feel more supervised.”* (Sup-Exp$_5$) *“We do not want to put pressure trough possible surveillance on the employee.”* (Pro-Exp$_1$) *“For me a strict separation of professional and private data is necessary.”* (Sup-Exp$_5$) *“You have to deliberate which personal data you are allowed to collect and what purpose this makes. This must be negotiated with the works council.”* (Sup-Exp$_5$) *“A smartwatch is a technical device that is connected to my body, and this fusion of internet and body creates a feeling of insecurity for me.”* (Sup-Exp$_5$)
Encryption	*“If a watch gets lost - especially outside the company premises - the data should not be directly readable.”* (Sup-Exp$_7$) *“I want our data to remain in our network and be encrypted.”* (Sup-Exp$_7$)

Table 24. Statements of the domain experts from practice according to DP$_7$

Finally, there are smartwatch related prerequisites. According to the statements presented in Table 25, the smartwatch should provide at least battery life for a complete shift, and it should be impact-, water-, oil- and acid-resistant. Due to hygienic factors and higher involvement of employees, a bring your own device or business smartwatch program was discussed.

Smartwatch Related Prerequisites	
Battery Life	*“A smartwatch should at least last one shift otherwise, there is a huge time loss since charging is impractical.”* (Sup-Exp$_6$)
Robustness	*“The device has to survive in our daily work environment including chemical and physical stress.”* (Pro-Exp$_1$)

Table 25. Statements of domain experts according to the smartwatch related prerequisites

Altogether, we substantiated the design principles with the conducted empirical studies. The validity of the design principles across the use cases is confirmed by the reference of domain experts from various scenarios.

4.4.6 Documenting the Design Knowledge

To document the design-knowledge acquired during the five design science research cycles, we formulate a nascent design theory according to Gregor / Jones (2007). As elaborated in section 4.4.5.1, we address the problem that ubiquitous and incidental access to information for mobile employees executing manual work is impossible with traditional tools and hardware. Hence, the objective of the smartwatch-based information system is to digitally and incidentally support mobile employees in collaborative workflows who are executing manual work and thus cannot operate standard mobile devices (e.g., smartphones). In section 4.4.5.2 we derived seven empirically founded design principles based on 28 meta-requirements that emerged during the design science research cycles. We demonstrated the artifact mutability by applying our artifact successfully in four scenarios found in practice. Based on our experience in practice the smartwatch-based IS often replaces or complements extant systems based on smartphones, terminals, or desktop PCs that require the users' full attention and hands for operation. We formulated six effects of an implementation of the proposed design theory concerning (1) ubiquitous access to digital information, (2) incidental communication, (3) capacity utilization, (4) reaction times, (5) process-knowledge, and (6) introduction of employees as testable propositions. The design theory is justified with a broad range of knowledge on the one hand acquired in the research domain like the Information Foraging Theory, the Media Synchronicity Theory, as well as related work on mobile, wearable- and smartwatch-based IS, and on the other hand in the practical domain during a workshop series, a usability study and four studies within typical use cases. As a principle of implementation, we demonstrated with the introduction of *watchIT* how to transfer the design theory into a software artifact. Expository instantiations have been presented within the four use cases (1) *smartActivity* in the production, (2) *supportWatch* in the support, (3) *smartSecurity* in the security service, and (4) *smartActivity* in the logistics each providing a situated implementation. We summarize all contributions in Table 26 providing the components suggested by Gregor / Jones (2007).

Component	Description
Purpose and scope	The objective of the smartwatch-based information system is to digitally and incidentally support mobile employees in collaborative workflows who are executing manual work and thus cannot operate standard mobile devices (e.g., smartphones).
Constructs	The constructs smartwatch, digital support, workflow, process guidance, unobtrusive notification, incidental operation, context awareness, collaboration, privacy, and elimination of information asymmetry were derived and are relevant for the design.
Principle of form and function	Through a review of smartwatch-related literature as well as a preliminary workshop series, a usability study, and four evaluation studies within typical use cases, we derived seven design principles, which were qualitatively and quantitatively founded: **DP_1:** Rely on a system architecture composed of a mobile standalone smartwatch application that can be operated hands-free and incidental, a responsive backend suited for devices with a higher display size allowing a clearer overview and a server providing the data infrastructure as well as an interface for paired systems. **DP_2:** Organize the workplaces in functional groups and assign devices based on their mobility demands. Allow workplaces to use administrative and complex operations in the backend due to their competencies. **DP_3:** Display individual and context-relevant key information on the smartwatch to reduce the cognitive load and provide extended data, including statistics and other visualizations in the backend. **DP_4:** Support collaboration through the exchange of tasks, immediate notifications with a subsequent acknowledgment, forwarding of tasks to colleagues, communication with text and voice, and multilingual user interfaces. **DP_5:** Guide the employee through the selection of contextual arranged tasks in workflows that can be built in the backend. **DP_6:** Analyze the employees' context with appropriate smartwatch sensors, including the location, motion patterns, and recognizable tags placed at real-world objects. **DP_7:** Respect employees' privacy with a strict policy of no acquisition and storage of person-related information and deactivating all functions of the smartwatch application outside of the corporate context. Protect and encrypt sensible corporate data during transmission and on the devices.
Artifact mutability	*WatchIT* can be utilized in production, support, security service, and logistics, as the evaluations suggest. Those scenarios cover a wide range of corporate scenarios, including mobile employees executing manual work, and can be transferred to further corporate constellations. Hence, there is evidence to assume that *WatchIT* can generally be utilized for process support in the corporate context.
Testable propositions	Following a comparative logic that smartwatch-based IS often replace extant stationary and mobile systems (e.g., desktop and smartphone solutions) that require the users' full attention and hands for operation, we formulate six testable propositions for our design. If a smartwatch-based IS respects the proposed design, then… **P_1:** employees gain ubiquitous access to digital information regardless of their demands on mobility and dependence on their hands at work **P_2:** employees can communicate more directly and efficiently while they less discontinue work **P_3:** the distribution of work is more efficient, and the capacity utilization of employees is increased **P_4:** unnecessarily repeated checking of task completion or occurrences is reduced, and reaction times of employees are increased, saving resources (e.g., time and materials) **P_5:** employees have higher process-knowledge with fewer uncertainties and decreased cognitive load **P_6:** the introduction of new employees with context-sensitive workflow guidance is more simple ... than with an extant system using traditional tools and hardware.
Justificatory knowledge	The overall design is grounded in the Information Foraging Theory, the Media Synchronicity Theory, related work on mobile-, wearable- and smartwatch-based IS, as well as a preliminary workshop series, a usability study, and four evaluation studies within typical use cases.
Principles of implementation	We provide w*atchIT* as an example of how to instantiate the design in the form of a software artifact. It can easily be configured, modified, and extended for future smartwatch-based IS.
Expository instantiation	We presented the four examples *smartActivity* (production), *supportWatch* (support), *smartSecurity* (security service), and *smartActivity* (logistics), each situated for a typical scenario that emerged in practice and applying the proposed design.

Table 26. Nascent design theory for smartwatch-based IS

4.5 Discussion

The study follows a strict design science research approach traversing five cycles and complies with the design science research guidelines by Hevner et al. (2004), differentiating from the action research methodology (Iivari / Venable 2009). (1) It produces the viable *watchIT* software artifact and the instantiations *smartActivity*, *supportWatch*, and *smartSecurity* for a various range of use cases. (2) It addresses the problem of information asymmetry and the process support with context-relevant information within corporate workflows where employees execute manual work and cannot operate common digital devices (e.g., smartphones). (3) The artifact's utility, quality, and efficacy are demonstrated in each DSR cycle with numerous domain experts during field studies, qualitative and quantitative interviews, and questionnaires. (4) The process produced verifiable research contributions in the form of extensive knowledge of designing smartwatch-based IS to support employees in the corporate context. (5) Research rigor is ensured by applying a research methodology, according to Peffers et al. (2007) in each DSR cycle. (6) While searching for a solution supporting employees executing manual work digitally, we identified smartwatches that emerged and became operational in the last decade, respecting determining practice conditions. (7) Finally, we presented the findings to researchers as well as practitioners and managers of various range of companies to assure communication of research.

As with any practice-oriented research study, some methodical limitations exist: First, the empirical foundation of the developed meta-artifact is predominantly based on evaluations from the previous use cases with a limited scope of companies. Besides, the participants mainly evaluate the artifact based on their impression during the demonstration, and they could only test the application for a short time-frame. To address this limitation, *watchIT* has to be transferred to more use cases with a broader range of involved companies. A long-term evaluation including a higher number of participating employees to analyze the practical effects in the daily work assessing the long-term impact of smartwatches in companies and challenges like technostress has to be conducted (Ayyagari et al., 2011). We expanded the narrow field of application caused by the paradigm of low-interaction, short-term, and proactive use of smartwatches (Dvorak 2007).

Although we utilized smartwatches' unique characteristics to overcome recent barriers concerning the ubiquitous exchange of information during manual work, smartwatches are not convenient in every situation. On the one hand, the form factor and the small display size impede a proper operation, particularly for older employees constricted in their visual and haptic abilities. On the other hand, smartwatches cannot be utilized whenever the hardware cannot endure the environmental influences or can cause damage, e.g., in paint rooms with explosion hazard.

Nevertheless, for practice, we created an applicable software solution for many scenarios. We introduce innovative technologies to support employees in workflows and enable digitalization for employees who cannot benefit from extant devices. This helps companies to keep pace with the competition through the consolidation of employees. Contrary to many recent Kanban-based task-management products, e.g., *MeisterTask* that provide smartwatch applications to display tasks, our software artifact *watchIT* exploits the full potential of smartwatches by a smartwatch-centered approach allowing an appropriate exchange of information, collaboration, workflow guidance, context awareness, and respects privacy (MeisterLabs GmbH 2020; Ohno 1988).

Within the research domain, our research contributes to the knowledgebase of mobile information systems. In line with Hobert / Schumann (2017a), we take advantage of smartwatches inheriting the characteristics of ubiquitous availability and hands-free operation of wearable computers to overcome common problems of hand-held mobile devices like smartphones or tablets. Thus, it contributes to overcoming limitations concerning hand-operation of existing IS studies in the domain of collaboration support (Syafar et al. 2014) and addressing the limited incidental process support (Zaplata et al. 2009b). The combination of a workflow with defined response options (DP_5) and context-awareness (DP_6) on the one hand overcome the problem of the small display size, and on the other hand, reduce the complexity (Zaplata et al. 2009a), aligning with the Cognitive Load Theory (Sweller 2011). We extended the knowledge about context-aware mobile applications summarized by Zhang et al. (2009) with smartwatches providing a broad range of sensors to recognize the environment. Besides the functional requirements, we integrated privacy into the design principles due to high frequently appeared privacy concerns applying the considerations of Jakobi et al. (2020) to the domain of the new smartwatch devices. Nevertheless, individual agreements with the workers' council are unavoidable. Furthermore, we were able to adopt the Information Foraging, and Media Synchronicity Theory to the newly forming field of smartwatch-based IS (Pirolli / Card 1999; Dennis / Valacich 1999). We confirmed that a combination of mobile and wearable computers with wireless technology leads together to increased effectiveness and accuracy (Smailagic / Bennington 1997).

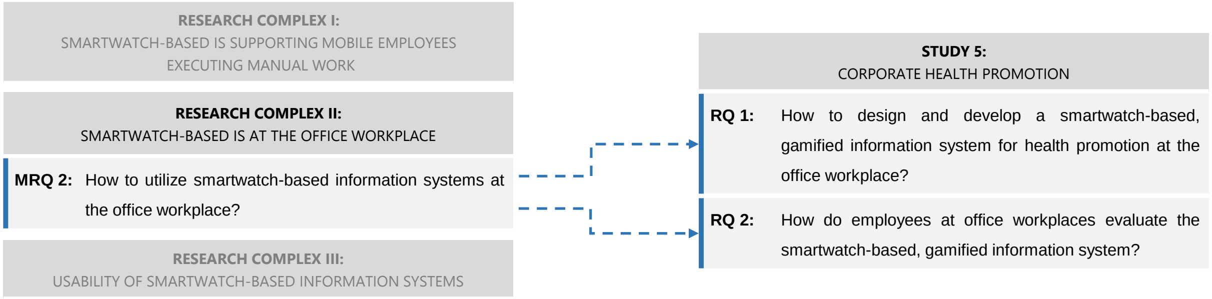
We created four level 1 design science contributions (Gregor / Hevner 2013) to address the introduced use cases in practice. The presented meta-prototype implementing the design principles forms the entrance to a level 2 contribution. The accumulated insights and knowledge can help to understand how to integrate smartwatches into the corporate context and how to design mobile information systems based on smartwatches to support employees in workflows. According to Gregor / Hevner (2013), we provided an entry to a level 3 design science contribution with the nascent design theory.

4.6 Conclusion

In this paper, we addressed the problem of digitally and incidentally supporting mobile employees in collaborative workflows who execute manual work and thus cannot operate standard mobile devices (e.g., smartphones). For that, we explorative elaborated on the underlying problems emerging in practice and investigated production, support, security service, and logistics scenarios during four design science research cycles. In this way, we cover a broad range of typical scenarios that can be transferred to various conditions in the corporate context. In a concluding fifth design science research cycle based on Peffers et al. (2007), we design and implement the smartwatch-based information system *watchIT* covering all mentioned scenarios with a holistic view. For that, we first identified and described the generalized problem within the context of the founding use cases. Complementary to the meta-requirements that emerged in the first four design science cycles, we deduced seven design principles. By designing and implementing the necessitated components for *watchIT* composed of a smartwatch application, a desktop backend, and a server infrastructure, we exemplarily showed how to transfer the design principles into a software artifact and contributed an applicable software solution for the practice. In an evaluation step, we gathered quantitative and qualitative feedback from various experts in practice. According to the participants, the unique features as collaboration, workflow guidance based on non-interrupting, immediate and location-independent information exchange, and context awareness of *watchIT* result in an improvement of the process and collaboratively. The evaluation especially accentuates the high importance of employees' privacy and participation during the introduction phase (Jakobi et al. 2020). Finally, we assembled the in the five design science research cycles acquired knowledge and contribute a nascent design theory according to Gregor / Jones (2007). Concluding, we addressed the underlying RQ while complementing the theory about smartwatch-based information systems. We contributed knowledge facilitating to design smartwatch-based IS and hence to foster smartwatch adoption in the corporate context.

II Smartwatch-based IS at the Office Workplace

This research complex addresses smartwatch-based information systems at the office workplace. This broadens and complements the view on the utilization of smartwatches in the corporate context in addition to the mobile context described in the first research complex. Though smartwatches are devices constructed for mobile use, the utilization in low mobile or stationary scenarios also has benefits due they exhibit the characteristic of a wearable computer and are directly connected to the employee's body. Various sensors can perceive employee-, environment and therefore context-related information and demand the employees' attention with proactive notifications that are accompanied by a vibration. MRQ 1 consequently elaborates on the utilization of a smartwatch-based IS at the office workplace. As depicted in Figure 38, Wesseloh et al. (2020b, study 5) refine this superordinate objective and assess (1) how to design and develop a smartwatch-based and gamified information system for health promotion at the office workplace with RQ 1 and (2) and how employees evaluate such a system with RQ 2. Consequently, this research complex provides an example of how to utilize smartwatch-based information systems at the office workplace and, in general, in stationary scenarios.



MRQ 2: How to utilize smartwatch-based information systems at the office workplace?

RQ 1: How to design and develop a smartwatch-based, gamified information system for health promotion at the office workplace?

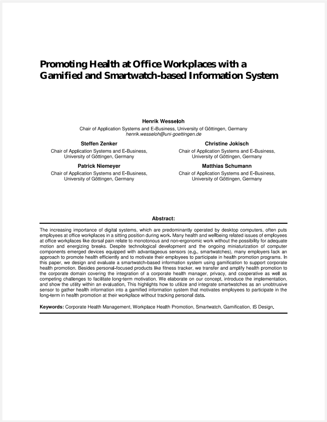
RQ 2: How do employees at office workplaces evaluate the smartwatch-based, gamified information system?

Figure 38. Refinement of the meta-research questions of research complex II

Supplementary material for the study is provided in appendix 0, including the detailed statistics of the evaluation and the translated questions of the questionnaire.

5 Corporate Health Promotion

Promoting Health at Office Workplaces with a Gamified and Smartwatch-based Information System



Promoting Health at Office Workplaces with a Gamified and Smartwatch-based Information System

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Abstract:

The increasing importance of digital systems, which are predominantly operated by desktop computers, often puts employees at office workplaces in a sitting position during work. Many health and wellbeing related issues of employees at office workplaces like dorsal pain relate to monotonous and non-ergonomic work without the possibility for adequate motion and energizing breaks. Despite technological development and the ongoing miniaturization of computer components emerged devices equipped with advantageous sensors (e.g., smartwatches), many employers lack an approach to promote health efficiently and to motivate their employees to participate in health promotion programs. In this paper, we design and evaluate a smartwatch-based information system using gamification to support corporate health promotion. Besides personal-focused products like fitness tracker, we transfer and amplify health promotion to the corporate domain covering the integration of a corporate health manager, privacy, and cooperative as well as competing challenges to facilitate long-term motivation. We elaborate on our concept, introduce the implementation, and show the utility within an evaluation. This highlights how to utilize and integrate smartwatches as an unobtrusive sensor to gather health information into a gamified information system that motivates employees to participate in the long-term in health promotion at their workplace without tracking personal data.

Keywords: Corporate Health Management, Workplace Health Promotion, Smartwatch, Gamification, IS Design.

Abstract: The increasing importance of digital systems, predominantly operated by desktop computers, often puts employees at office workplaces in a sitting position during work. Many health and wellbeing related issues of employees at office workplaces like dorsal pain relate to monotonous and non-ergonomic work without the possibility for adequate motion and energizing breaks. Despite technological development and the ongoing miniaturization of computer components emerged devices equipped with advantageous sensors (e.g., smartwatches), many employers lack an approach to promote health efficiently and motivate their employees to participate in health promotion programs. In this paper, we design and evaluate a smartwatch-based information system using gamification to support corporate health promotion. Besides personal-focused products like fitness trackers, we transfer and amplify health promotion to the corporate domain covering the integration of a corporate health manager, privacy, and cooperative as well as competing challenges to facilitate long-term motivation. We elaborate on our concept, introduce the implementation, and show the utility within an evaluation. This highlights how to utilize and integrate smartwatches as an unobtrusive sensor to gather health information into a gamified information system that motivates employees to participate in the long-term health promotion at their workplace without tracking personal data.

Keywords: Corporate Health Management, Workplace Health Promotion, Smartwatch, Gamification, IS Design

Citation: (Wesseloh et al. 2020b, study 5) Wesseloh, H.; Zenker, S.; Jokisch, C.; Niemeyer, P.; Schumann, M.: Promoting Health at Office Workplaces with a Gamified and Smartwatch-based Information System. Under Review. 2020.

5.1 Introduction

Employee's absence from the workplace due to illness ranges between 4 to 18 days per year (WHO 2019) and is estimated to cost about 2.5 % of gross domestic product (GDP) within the European Union (Eurofound). In recent years, an increasing number of this absenteeism has been observed in some parts of Europe – especially in Germany (WHO 2019; OECD 2020). In 2018, for example, the German state of Baden-Württemberg recorded almost a doubling of the total number of sick days taken over the past ten years – from 33.5 million to 65.36 million (BMG 2019). According to total days of absence, musculoskeletal disorders are at the top with a share of 23.8 %, followed by respiratory diseases (16.4 %) and mental disorders (15.7 %) of employees (Knieps / Pfaff 2019).

The causes of health problems in the workplace are manifold and can vary depending on the individual, the job, or the workplace (Burgard / Lin 2013). In the context of this article, we, therefore, focus on the employees at office workplaces. In comparison to craft professions, these workers are more subject to mental disorders caused by technostress due to the effects of digitization (Ayyagari et al. 2011). However, also the predominant sedentary and sitting behavior in front of the computer screen has a negative impact on health, causing, e.g., lower back pain (Bontrup et al. 2019) computer vision syndrome (Blehm et al. 2005). These impairments can lead to personal perceived missing well-being, a loss of productivity, and job performance – even in the case of presenteeism (Johns 2010).

Since office workplaces became an increasing share during the digitalization, companies can highly benefit from implementing occupational health measures as a part of their human resource management to counteract the described consequences of a digital workplace. However, in many companies, corporate health promotion is not realized and integrated into the daily work of their employees to a beneficial degree (Ulich / Wülser 2017). Traditional interventions, including health tips and sports program offers, cause high demand for human resources, are difficult to scale and be used in a broad range of domains (Kaiser / Matusiewicz 2018). The digitization of health promotion creating extensive individualization through health apps, *e. g.*, on smartphones or fitness trackers, is widespread and popular in the private domain. Nevertheless, such applications are difficult to transfer to the corporate context. (1) There are privacy concerns. (2) there is no aggregated feedback to a corporate health manager who can react to organizational deficits. (3) In many companies, there is a rigid code of conduct that inhibits individual empowering breaks. (4) Moreover, there is little problem awareness of healthy employees and long-term motivation to attend health promotion programs. On the other hand, employee assistance programs, or holistic health platforms (Wilson et al. 2014), in turn, exhibit potential for personalized health promotion. Even though these tools can support existing processes, they have been implemented in merely 35.7 % of the companies (Kaiser / Matusiewicz 2018). In particular, ensuring data protection and data security, as well as user acceptance, are cited as the central challenges of introducing digital solutions nowadays (Kaiser / Matusiewicz 2018; Burkhard et al. 2010). As outlined by Zenker (2020, study 3), smartwatches supply a broad range of sensors providing data that can be utilized to access health-related information. Integrated into a digital information system that follows a strict privacy focus, a smartwatch can become an unobtrusive sensor that can be found at employees' wrists in many cases nowadays. Such a system can provide individual feedback and recommendations for offers (e.g., courses) of an employer.

Besides, employees themselves lack the motivation to participate in health promotion programs (Dötschel 2018). However, intrinsic motivation is the prerequisite for health-promoting activities to affect and to change behavior in the long term (Lippke / Sonia 2018). Therefore, motivational approaches are a topic in corporate health management and, at the same time, interest in gamification – *the use of game elements in a non-game context* (Deterding et al. 2011). There are already several studies on gamification in the context of health and wellbeing (cf. Johnson et al. 2016; Koivisto / Hamari 2019). Additionally, the potential to promote motivation and thus change behavior has also been analyzed (and partly confirmed) in many other contexts, e.g., education or marketing (Hamari et al. 2014; Osatuyi et al. 2018).

Therefore, this research contribution aims to combine smartwatches and gamification's favorable characteristics, develop a novel digital system for corporate health management, and evaluate its utility. We use smartwatches as an unobtrusive sensor recording health-related values and, in this way, create an information system that, on the one hand, strictly respects the privacy and, on the other hand, enables a corporate health manager to access an aggregated overview to gain insights about organizational deficits. Besides, the problem awareness and long-term motivation of employees is encouraged with elements from the domain of gamification as cooperative as well as competing challenges. Accordingly, we address the following two research questions within this article:

RQ1: How to design and develop a smartwatch-based, gamified information system for health promotion at the office workplace?

RQ2: How do employees at office workplaces evaluate the smartwatch-based, gamified information system?

To answer these research questions, the remainder of this article is structured as follows: First, we present definitions of basic terms in the field of gamification, smartwatches, and corporate health management and outline related research and practice in section 5.2. Second, we describe our research method, including a mixed-method approach in section 5.3. By applying the given research framework to our problem domain, we illustrate the system's design and evaluation in section 5.4. Finally, we discuss our results in section 5.5 and outline our research contributions for theory and practice in section 5.6 during the conclusion.

5.2 Theoretical Foundation and Practice

5.2.1 Health and Corporate Health Management

According to the preamble of the Constitution of the World Health Organisation (WHO), health is defined as *“a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”* (WHO 1948). Various legal regulations necessitate companies to ensure that working conditions are conducive to health (Verra et al. 2019), so companies often implement corporate health management as a part of their human resources management (HRM).

> **Corporate health management** (CHM) refers to a specific management system that aims *“to promote a company’s health situation holistically and sustainably through continuous improvement processes”* (Badura, Schröder, & Vetter, 2010)

For a comprehensive approach to support employee well-being, organizations rely on three central health management systems: occupational safety and health (OSH), workplace health promotion (WHP), and healthcare and ill-health management (IHM) (Mellor / Webster 2013).

Occupational safety and health management describes a combination of planning and reviewing organizational and consultative arrangements and the specific program elements that work together in an integrated way to improve health and safety performance at the workplace (Gallagher et al. 2003). It controls and manages mandatory OSH policies and implements procedures to ensure the critical health and safety issues affecting the staff (Mellor / Webster 2013). Therefore, its main task is to *protect* employees from harm, e.g., by preventing accidents or injuries at the workplace when working with dangerous machines or substances.

Healthcare and ill-health management aim to overcome an employee’s incapacity for work, prevent a renewed incapacity for work, and preserve the employee’s job (Schlinkheider 2018). This system includes absence management, return to work procedures, and employee assistance programs (Mellor / Webster 2013). The main task of IHM is to *react* adequately to employees’ illnesses so they can still be productive.

Workplace health promotion deals with measures that go hand in hand with greater self-determination and thus empowerment to strengthen health, such as the participation in training and courses or community activities (Ulich / Wülser 2017). It is “*a process of enabling people to increase control over, and to improve, their health*” (WHO 1998). The main task is to *prevent* employees’ long-term health issues in the workplace.

Whereas OSH and IHM procedures are mandatory for companies in some countries due to legal regulations and laws, WHP predominantly remains a voluntary HRM activity (Verra et al. 2019). As a result, several management systems for OSH and employee assistance programs already exist.

However, in the case of WHP, a prominent digital solution – to the best of our knowledge – does not exist yet. We want to contribute to close this gap and focus on the systematic development of an information system for WHP, as already suggested by Kaiser / Matusiewicz (2018). Table 27 summarizes the organizational structure of corporate health management and shows the research gap in existing information systems for workplace health promotion.

Human Resources Management (HRM)			
Branch	**Corporate Health Management (CHM)**		
Subdivision	**Occupational Safety & Health (OSH)**	**Healthcare & Ill-Health Management (IHM)**	**Workplace Health Promotion (WHP)**
Main goal / task	Protect	React	Prevent
Legal requirements	Mandatory	Mandatory	Voluntary
Information systems in place	OSH Management Systems	Employee Assistance Programs	-- *Research Gap*

Table 27. Organizational structure of corporate health management as branch of HRM

5.2.2 Smartwatches

Due to technological progress and the continuing miniaturization of computer components, a new category of devices with unique characteristics emerged in the last decade. In particular, the so-called wearables are worn on the user's body, permanently active, and designed for mobile use (Boronowsky et al. 2008). These microcomputers can assist the user in everyday activities or work processes and provide (proactive) support (Dvorak 2007). Wearable computer comprise clothing with integrated electronic systems and devices like smart glasses and smartwatches. Smartwatches currently dominate the wearable computer market, as they are the most accepted in the social environment, and the users feel comfortable wearing the device due to the high similarity to ordinary watches (Choi / Kim 2016).

Smartwatches are a special form of a mobile computer in the shape of a digital wristwatch (Cecchinato et al. 2018). They are composed of standard computer hardware such as a processor, memory, and battery. Besides, they are equipped with various sensors and wireless interfaces (as W-LAN, Bluetooth, or GSM) and can be operated with a touchscreen, voice control, motion gesture control, or several hardware buttons as well as a digital lunette (Bieber et al. 2012; Chuah et al. 2016; Pascoe / Thomson 2007). Since they run a hardware-independent operating system, which can be extended by installable applications, they delimit from other mobile devices with a similar shape like fitness trackers. For this paper, we use the following definition:

> A **smartwatch** is a standalone, miniaturized computer in the form of a wristwatch equipped with a touchscreen and hardware buttons for operation, various sensors to gather information about the real-world context, and wireless interfaces for communication. It runs a hardware-independent operation system which functionality can be extended by custom applications.

Smartwatches are worn directly on the users' body, are therefore always available and can demand a users' attention proactively with haptic feedback like vibrations to initiate interactions (e.g., react to received notifications), independently of a specific location or time (Boronowsky et al. 2008; Jiang et al. 2015; Rhodes 1997). Due to the small form factor, smartwatches are usually limited to simple input and output options (Malu / Findlater 2015). Besides the direct operation through a user, a smartwatch can passively gather information about the environment (e.g., for context detection) or the person wearing it. Table 28 summarizes the broad range of smartwatch sensors (Reeder / David 2016) and highlights the possible application to gather health-related data.

Sensor	**Information**	**Health Application**
Accelerometer	Tri-axial acceleration of the wrist	Detection of various activities like step counting, eating, or gestures
Gyroscope	Tri-axial rotation of the wrist	
Microphone	Sound intensity of the surrounding	Determination of the noise stress
Optical sensors	The intensity of light angle reflection	Measurement of the heart rate
Contact sensors	Temperature	Monitoring of the body temperature
Barometer	Air pressure	Detection of unfavorable air conditions
Ambient light sensors	The intensity of the surrounding light	Monitoring of an eye-friendly lighting

Table 28. Sensors of common smartwatches indicating their application to gather health-related information

The utilization of smartwatches in the corporate context is a recent research subject and can take many different forms. In general, smartwatches allow permanent access to the digital workplace, to inform employees proactively, strengthen collaboration with an immediate exchange of information, guide employees through processes, and support workflows in an incidental and hands-free way. This is especially important for employees performing manual work such as industrial (Zenker / Hobert 2019, study 1), support (Zenker et al. 2020b, study 2), and security (Zenker 2020, study 3) use cases. In particular, security employees can benefit from the smartwatch sensors analyzing health and context parameters to, e.g., detect attacks or accidents. Since smartwatches exhibit limited input and output capabilities due to the touchscreen and small form factor, the usability of smartwatch applications is a crucial factor for a successful long-term realization in a company (Zenker / Hobert 2020, study 6).

Since smartwatches are permanently connected to the body, they provide ample opportunities in personal health management. Many manufacturers, as *Google* and *Apple,* already integrated health apps into their devices. There are also several studies concerning health promotion with smartwatches in the research domain. Kim et al. (2019) analyzed the impact of smartwatches on promoting healthy behavior and figured out that smart devices can foster health awareness. Esakia (2018) developed a smartwatch centered system facilitating group processes to encouraging physical activity. However, these applications have problems with data privacy since health information is shared worldwide through the internet. Furthermore, they are primarily developed for the private domain conflicting with the behavioral conventions at work and lack an approach for a holistic application within a company as well as the integration of a corporate health manager.

5.2.3 Gamification

In the scientific literature, definitions of gamification include two central dimensions: On the one hand, the use of typical *game elements* and, on the other hand, its application in a *non-game* context (Deterding et al. 2011). Depending on the research perspective, these dimensions are concretized and extended by an intended outcome or setting (Schöbel et al. 2020). Table 29 summarizes a selection of context-independent definitions that address different aspects of gamification.

Source	**Definition**
Deterding et al. 2011	*“The use (rather than the extension) of design (rather than game-based technology or other game-related practices) elements (rather than full-fledged games) characteristic for games (rather than play or playfulness) in non-game contexts (regardless of specific usage intentions, contexts, or media of implementation).”*
Hamari et al. 2014	*“Gamification has been defined as a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes.”*
Werbach 2014	*“The process of making activities in non-game contexts more game-like.”*
Bui et al. 2015	*“The application of game design elements in non-game products or services to steer users’ behaviors toward preferred outcomes.”*

Table 29. Overview of context-independent gamification definitions

The short version of the definition of Deterding et al. (2011), i.e., “*the use of game design elements in non-game contexts*,” is cited in most contributions due to its general applicability and is therefore considered a prominent definition for gamification. This “*elementary definition*” (Werbach 2014) consists of four semantic components, the meanings of which are specified or supplemented by other mentioned definitions (Sailer et al. 2017):

1. **Game**. According to Caillois (2001), there are two ways of playing that can be distinguished: *Paidia* (playing) is the free, unregulated playing and appears, for example, as a child’s play. *Ludus* (gaming) is the game with its rule-based and goal-oriented features. Constant feedback

and free will to play are also characteristic of games (McGonigal 2012). Due to the use of game design elements, gamification must correspondingly be rule-based, goal-oriented, and perceived as voluntary by the user (Deterding et al. 2011).

2. **Elements**. Gamification is not about complete games but about individual building blocks that are characteristic of games (Deterding et al. 2011). Accordingly, these elements are intended to create gameful user experiences, which are typical for games, such as fun and enjoyment (Werbach 2014; Huotari / Hamari 2015).

3. **Design**. Gamification is understood as a particular form of game design but is not related to game-technological aspects like graphic engines or game controllers (Deterding et al. 2011). The process includes not only the use but also the conscious selection, design, and integration of game design elements (Werbach 2014).

4. **Non-game context**. Gamification refers exclusively to non-game-related contexts (Deterding et al. 2011) and can be integrated into products or services (Bui et al. 2015; Hamari et al. 2014), as well as individual activities or holistic processes (Werbach 2014). Therefore, the concept is not limited to being a digital (online) solution (Deterding et al. 2011). The context is usually associated with an intended goal, to guide a person's behavior to desired results (Bui et al. 2015) or to increase the value of activity for the person (Huotari / Hamari 2015). Explicit gamification goals are, for example, the promotion of motivation and performance (Sailer et al. 2017).

Due to the essential characteristics, according to Deterding et al. (2011), we define gamification for the scope of this paper as follows:

> **Gamification** describes the design process of enhancing information systems with game design elements in a non-game context to evoke gameful experiences.

The use of gamification for health and wellbeing has been discussed in various research contributions, as two literature reviews summarize. Johnson et al. (2016) found in their literature review the potential advantages of gamification in the context of health and wellbeing, like supporting intrinsic motivation, broad accessibility, applicability, and appeal, as well as cost-benefit efficiency, regular life fit, and direct wellbeing support through positive experiences. They identified an everyday use of rewards, leaderboards, and avatars to support physical activity (including nutrition) and mental health, concerning wellbeing, personal growth, and flourishing as well as stress and anxiety. Besides, the literature review of Koivisto / Hamari (2019)(2019) in the context of promoting physical activity mostly summarized positive (or at least neutral) effects throughout different comparison studies. Most gamification approaches focused on the pattern of implementing points, goals, and leaderboards as well as collaborative affordances, like team mechanics (Koivisto / Hamari 2019). Most of the reviewed studies targeted private users. In contrast, use cases in corporate health management remain scarce – except for two contributions: First, Lier / Breuer (2019) found that the inclusion of game design elements in a WHP program was significantly positively related to physical activity outcomes: employees who participated in the gamified challenges took considerably more steps than employees who did not participate. Second, Lowensteyn et al. (2019) concluded that WHP programs that evolve and focus on fun and competitive challenges might support long-term participation, behavior change, and sustained improvements in clinical outcomes (e.g., reduced stress and improved physical activity). Even though the limitations stress the validity of these findings as both studies had a risk of selection bias and lacked an actual control group (i.e., a WHP program without gamification), we believe their results are valuable to us, as it generally shows that digital gamified WHP systems can contribute towards a healthy workplace.

5.3 Research Design

To target the research gap and the corresponding research questions regarding a gamified and smartwatch-based information system for the corporate health management outlined in the preliminary section, we apply a research approach inspired by the problem-centered design science process model of Peffers et al. (2007). We, therefore, outline the theoretical or methodical foundation used for each step accordingly.

First, designing a gamified and smartwatch-based information system for the corporate health management for employees at office workplaces is grounded in the problem identification phase (step 1). For this, we rely on an extensible literature review based methodically on Webster / Watson (2002), Fettke (2006), and vom Brocke et al. (2009). With the employee at an office workplace as the identified subject of investigation, we derive requirements as our solution's objectives (step 2) based on the literature. We carefully analyzed and structured approaches from the literature to build the gamified and smartwatch-based information system addressing the previously described problems. According to the research process model, we designed and developed (step 3) the software prototype named *healthWatch* based on the elaborated requirements. For this, we draw upon the MDA framework (Hunicke et al. 2004) and Self-Determination Theory (SDT) (Deci / Ryan 1985). Subsequently, we demonstrated (step 4) our software-artifact to various decision-makers in corporate health management as domain experts. For this, we presented a realistic scenario to facilitate an easy understanding of the concept. Finally, we also asked 29 employees at different office workplaces to evaluate (step 5) the system during an online laboratory experiment with a qualitative and quantitative questionnaire including items, which we adapted from the *Intrinsic Motivation Inventory* (IMI) (Deci et al. 1994) and the *Technology Acceptance Model* (TAM) (Davis 1989).

Figure 39 illustrates our overall research design inspired by Peffers et al. (2007) to address the two research questions.

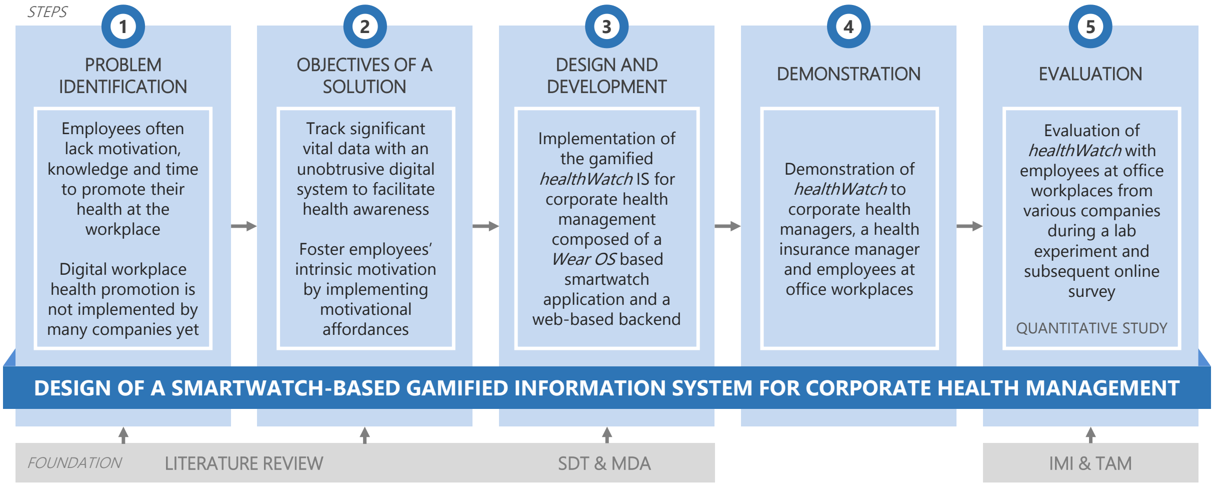


Figure 39. Overall research design inspired by Peffers et al. (2007)

5.4 Design of the *healthWatch* Information System

5.4.1 Problem Identification

To outline common problems concerning corporate health management, we carefully analyzed the literature and a scenario at a large-scale university, including a various range of office workplaces with different professional backgrounds. Like in the considered scenario, many companies have a specialized person or department for corporate health management. At the sample university, this department provides health promotion content in the shape of advice (e.g., positioning computer monitors ergonomically) and videos introducing health-promoting exercises. On the one hand, the critical problem is that this content is not well visible (merely advertised at the bottom of newsletters) and, on the other hand, many employees do not feel addressed by such programs since they lack individuality.

Besides, the communication of a health manager to the employees is very unidirectional, and there is little feedback. Since office workplaces differ in operational procedures and work intensity, they have unique burdens that require actions tailored to them. An objective comparison of departments becomes virtually unattainable as a result. Hence, corporate health managers are very limited to implementing health promotion supply in the everyday flow of work in cooperation with the employer to increase the well-being of the employees.

Employees at office workplaces often lack the problem awareness of corporate health promotion, and the upcoming exertion seems to hide the benefits of attending such programs. Overall, there is little motivation to regularly invest time in their health, resulting in better conditions and work performance. Especially when employees promote their health in the private sphere, e.g., exercising sport, they feel patronized by additional advice. Ultimately, there is the problem of privacy and data governance (Vesselkov et al. 2019). Health-related information is particularly legally protected, and a majority of employees do not want their employer to access such personal details.

An approach to provide individually adapted health promotion offers requires a lot of workforce and time, making it expensive and difficult to scale. Weiner et al. (2009) highlight two significant problems of adapting corporate health promotion programs to the individual needs of the company and achieve employees' acceptance for a new program during the implementation of comprehensive worksite health programs.

5.4.2 Objectives

In the sense of a structured development process, the identified problems need to be addressed during requirements engineering. We like to support corporate health promotion with a digital information system, reduce the required workforce, and ensure good scalability despite providing high individuality. This system has the primary objectives to enable bidirectional communications of employees and the corporate health manager, including feedback, to analyze health data to address the unique burdens of each department, to respect the privacy of health-related personal data, to make health advice more visible, and to establish high long-term motivations of the employees to use the system. We structure the resulting detailed objectives in (1) motivational requirements and (2) functional requirements.

5.4.2.1 Motivational Requirements

To address the problem of lacking employees' involvement in WHP programs, we must consider motivational requirements. This motivation can be referred to as "*the process whereby goal-directed activities are instigated and sustained"* (Schunk et al. 2010). In general, motivational affordances play a vital role in the design of information and communication technology (Zhang 2008). In our case, we especially want to support users' intrinsic motivation, as it is an essential prerequisite for sustainable healthy behavior. Deci / Ryan (2000) define intrinsically motivated behavior as "*those that are freely engaged out of interest without the necessity of separable consequences."* To maintain such behavior, the needs for autonomy and competence must be satisfied (Deci / Ryan 2000). We, therefore, establish the motivational requirements on two acknowledged motivational theories, which are briefly summarized:

Goal-Setting-Theory. To guide employees towards a correct healthy behavior in the first place, we draw upon the postulated *Goal Setting Theory* (GST) by Locke / Latham (1991). GST states that goals and their respective feedback influences motivation. Relevant factors are goal *specificity* and *difficulty* as well as an individual's goal *identification* and goal *acceptance*. Besides, feedback affects the direction, intensity, and endurance and promotes the continuation and, if necessary, correction of activities to achieve a goal.

Cognitive Evaluation Theory. In order to fulfill the psychological needs, we relied on Deci / Ryan's (1985) *Self-Determination Theory* (SDT) and especially its underlying *Cognitive Evaluation Theory* (CET) for a scientific approach to support autonomy, competence, and thus intrinsic motivation. CET states that the experience of autonomy and competence, but also the feeling of social relatedness, are decisive for the development or promotion of intrinsic motivation (Deci / Ryan 2000). Extrinsic rewards, on the contrary, do not necessarily have to corrupt intrinsic motivation. This effect depends on the individual perception of whether an extrinsic event is perceived as informative or controlling, resulting in a corrupting effect (Vansteenkiste et al. 2010).

To tailor the information system specific to the necessary conditions for (intrinsic) motivation, we derived six motivational requirements that target the basic psychological needs for *autonomy*, *competence,* and *social relatedness* as well as the aspect of effective *goal setting*. To satisfy the basic psychological need for autonomy, we identified three aspects, which can be transferred into a motivational requirement:

Voluntariness. Voluntariness can be understood as the vital aspect of self-determined, intrinsic action (Deci / Ryan 2000). To promote the user's motivation, using an information system to support corporate health management must remain voluntary and should not be considered an obligatory activity.

Freedom of choice. Individual choices are essential for the experience of autonomy – this also applies to health education (Deci / Ryan 1985). Therefore, the users should have a certain degree of freedom of choice within the application to customize their own user experience.

Anonymity. External pressure impairs the experience of autonomy and thus the intrinsic motivation (Deci / Ryan 1985). In the context of workplace health promotion, tracking vital data often is regarded as an intrusion into privacy (Kaiser / Matusiewicz 2018). Employees might not want their superior to know about their specific health issues. Therefore, users' health data must not only be protected in terms of privacy and data security but must also be made anonymous in order to prevent any backtracing to individuals and to avoid the feeling of surveillance by the employer (Rimbach 2018).

The basic need for competence is strongly affected by positive or negative feedback (Deci / Ryan 2000) and goal characteristics. Accordingly, the following motivational requirements regarding the feedback that users will receive from the information system and its goal-setting must be taken into account:

Informative feedback. Controlling feedback inhibits the experience of autonomy because it puts pressure on users. On the other hand, informative (non-controlling) feedback, on the other hand, promotes the experience of competence or autonomy (Ryan et al. 2006). Feedback for users of our system must therefore consider the aspect of informativeness since it can strengthen intrinsic motivation and also effective learning (Deci / Ryan 1985).

Clear goals. The more precise and demanding a declared goal is, the greater the motivational effect can be, as long it aligns with personal interests and capabilities (Locke / Latham 1991). Therefore, the information system needs to provide clear and feasible goals in terms of specificity and difficulty.

The last motivational requirement can be derived from the basic psychological need for social relatedness:

Group activities. People strive for connections in social groups since they influence the experience of social relatedness (Deci / Ryan 2000). In order for users to see themselves as a part of the social community, the system should provide group activities, so users get to interact with each other.

Table 30 summarizes the motivational requirements and their implications on the basic psychological needs.

R_M	Description	
M_1	Allow employees to voluntary use the information system at the workplace	A
M_2	Allow employees to customize their type of use freely	
M_3	Ensure anonymity to avoid the feeling of surveillance or backtracing by the employer	
M_4	Provide informative (non-controlling) feedback for users	C
M_5	Provide clear and feasible health goals for employees	
M_6	Support group activities and interaction among users	R

R_M: Motivational requirement; A: Autonomy; C: Competence; R: Relatedness

Table 30. Motivational requirements

5.4.2.2 Functional Requirements

The functional requirements should, in detail, describe how the information system conceptually addresses the identified problems. Therefore, we traverse the previously motivated problems and explain how we like to handle them as a crucial step during the design phase. The resulting requirements are summarized in Table 31.

Individuality & scalability. The need for individually concerted health promotion that requires a lot of effort, time, and human resources, makes it challenging to scale standard health promotion programs to a higher number of employees. To create a central platform that provides individual information, a digital system can automate repeating tasks and relieves the work of a corporate health manager significantly.

Unidirectional exchange of health-related information. As the corporate health manager likes to obtain health and well-being related feedback from the employees, analyze it and then apply individual measures (e.g., advice, course offers, or organizational modifications), a digital system has to gather health information. The employees should be free in their movement and not deviate from their work due to an inappropriate device resulting in R_{F1}. As further feedback should not occupy their work time,

R_{F4} signifies that this procedure should be incidental. To enable the corporate health manager to compare data of different departments and to analyze the unique burdens of these employees, the system should provide filters and visualizations covered by R_{F7}. Finally, there have to be functionalities allowing treatments or actions in response to the situation. On the one hand, health promotion courses should be implemented, as stated in R_{F8}. On the other hand, supplementary content like advice, exercises (e.g., in the form of micro-content) have to be provided as R_{F9} outlines.

Problem awareness. Because many employees are not aware of health-related issues and feel not addressed by standard programs, the system should provide key figures describing an employee's health status. In this way, R_{F2} reveals personal deficits and facilitates the motivation to participate in a health promotion program. To establish a long-term effect, the system should visualize the data over time, indicating the individual progress specified in R_{F5}.

Visibility. To make health and well-being related information more visible in daily life, the system should be able to display notifications. As summarized in R_{F3}, these should be non-distracting that the employee can concentrate on the work.

Privacy. The problem of surveillance and the exceedingly high legal protection of health-related personal data necessitate consideration from the bottom up. A role management component described by R_{F6} restricts the availability of personal data only to permitted people like the corporate health manager with special privileges. Besides, we store and display health-related data only in an aggregated and hence anonymized form (R_{F7}).

R_F	Description	
F_1	Record health data using a mobile and unobtrusive device on the employee's body ubiquitously	SW
F_2	Provide key figures representing a user's health status that can be accessed incidentally	
F_3	Display non-distracting notifications	
F_4	Request user feedback incidentally	
F_5	Provide an overview that allows a user to access their health status and progress quickly	WA
F_6	Manage users and attribute their roles with adequate levels of privileges	
F_7	Filter and aggregate anonymized health data to allow for analysis	
F_8	Display and manage health promotion courses	
F_9	Provide and manage supplementary health promotion content	

R_F: Functional requirement; SW: Smartwatch application; WA: Web application

Table 31. Functional requirements

5.4.3 Design and Development

As outlined in the previous sections, the described scenario includes employees at office workplaces. Their work is stationary, and they stay at their desk in a sitting position. However, due to some distant (e.g., operating the copier) and previously motivated health-related activities, a mobile digital device have to connect the employee to the information system. Also, due to R_{F1}–R_{F4}, this device has to be unobtrusive, incidentally to use, and non-distracting. Combined, a smartwatch provides all characteristics and can serve as the device on the user's body to record the health data and display notifications as well as key figures. The functional requirements R_{F5}–R_{F9} necessitate a device that provides a good overview and allows complex operations that exceed the capabilities of a smartwatch. Because employees at office workplaces usually work at a desktop computer, we utilize it to display a web-based backend, where besides a browser, no installation of additional software is required. Overall, we design the *healthWatch* information system (see Figure 40), which is composed of three technical components: (1) a native *Android Wear OS*-based smartwatch application, (2) a web component, which can be operated using a browser on a desktop computer, and (3) a server, which operates the whole system offering all interfaces and integrating the database. The institutions' wireless network connects all components in a fast, reliable, and secure way.

The native smartwatch-application can be installed on every typical smartwatch running *Wear OS.* We rely on this platform since it is free and open-source and is, unlike *watchOS* (*Apple*), available for a broad range of smartwatches from different manufacturers. The application runs exclusively at the workplace and can be deactivated in the private scope to prohibit surveillance abuse. It records health-related data with various sensors, provides quick access to key figures, and displays notifications emphasized with a vibration.

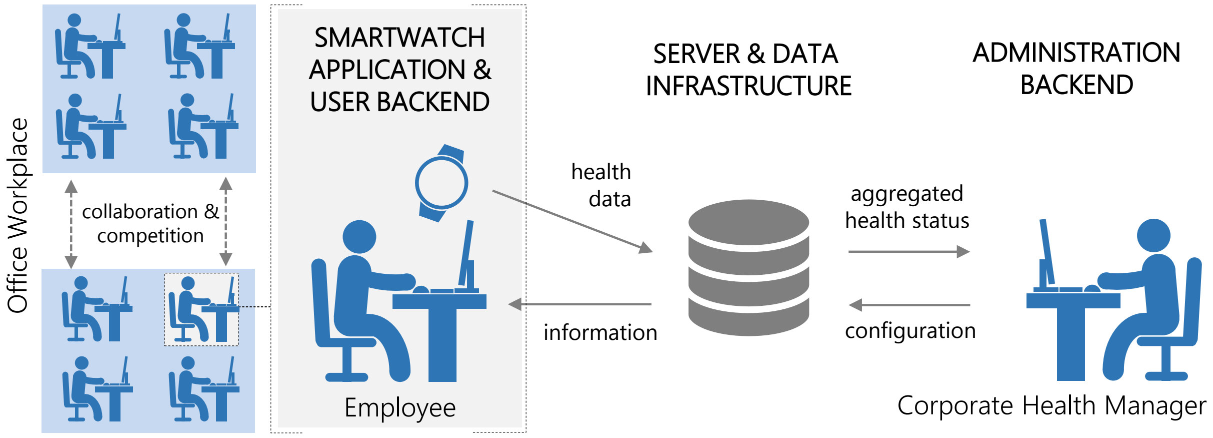


Figure 40. System architecture of *healthWatch*

The web-based backend is the central component of the *healthWatch* information system and is accessed in a browser using a configured domain or IP address. It allows employees to access their health profile, corporate health managers to get an overview of the actual situation, and provides administrators a backend to, e.g., manage user accounts on a stationary device, like a desktop computer. This ensures an adequate overview and the possibility of complex operations with decent display size. In order to protect the system from unintentional access, it requires a login, including a password. Once logged in, employees can connect their smartwatch to the system. For that, the smartwatch application generates a unique device token that is used for identification and authentication. This token can be inserted in the profile to allow an exchange of information.

For the server component, we rely predominantly on the scripting language *PHP* to benefit from its abilities related to web applications. In this way, the web-based component is empowered with modern web technologies like *HTML5*, *CSS,* and *JavaScript* to provide a good user experience and usability. The smartwatch application communicates with the server across an integrated REST interface. For data storage, we choose a relational *MySQL* database. To ensure easy applicability in practice and a high potential utility, we pick well-known and approved technical approaches at the server-side.

After we defined the basic system architecture, we modeled different use cases of the information system and thus transferred the requirements into system features. Therefore, we differentiated the required functionalities from the individual employee's perspective, the corporate health manager, and the technical administrator. Additionally, we identified features that could also be useful on the native smartwatch application, despite its small form factor.

The following **core functions** and features of *healthWatc*h are intended for **employees** and are described subsequently:

Health tracking. After installing the native application on the smartwatch, the employees must first connect it to the web-based component to enable the data exchange [»$\boldsymbol{R_{F1}}$] between the smartwatch and the server as considered in the system architecture (see Figure 40). Then, the smartwatch continuously sends the recorded vital parameters of the user to the server. For our prototype, we use the optical sensor to measure the pulse, the accelerometer to record the steps, and the gyroscope and accelerometer to detect a drinking motion [»$\boldsymbol{R_{F1}}$]. Whereas *Wear OS* provides native functions to read and analyze the sensor data regarding the heart rate and to count steps (Google and Open Handset Alliance 2020), a comprehensive approach to detect the drinking frequency has to be developed. For that, we first recorded and analyzed drinking motions using the acceleration sensors of a smartwatch, assuming that the user wears the smartwatch on the arm, which carries the glass or bottle. Figure 41 shows sample recordings, including two axes (X and Y) of the accelerometer and one axis (Z) of the gyroscope after ten representative drinking motions. We highlighted the average of the samples in blue and the deviation in grey span lines.

The data illustrates that we can identify different phases of a drinking motion, which can be utilized to reveal the drinking behavior of a user whenever they are detected in this specific sequence. In phase (1), the user guides the hand to the vessel resulting in a planar acceleration on the x-axis (top) with a minor rotation of the wrist (bottom). Now the vessel is lifted to the mouth and tilted (2), accelerating and rotating the smartwatch on all axes.

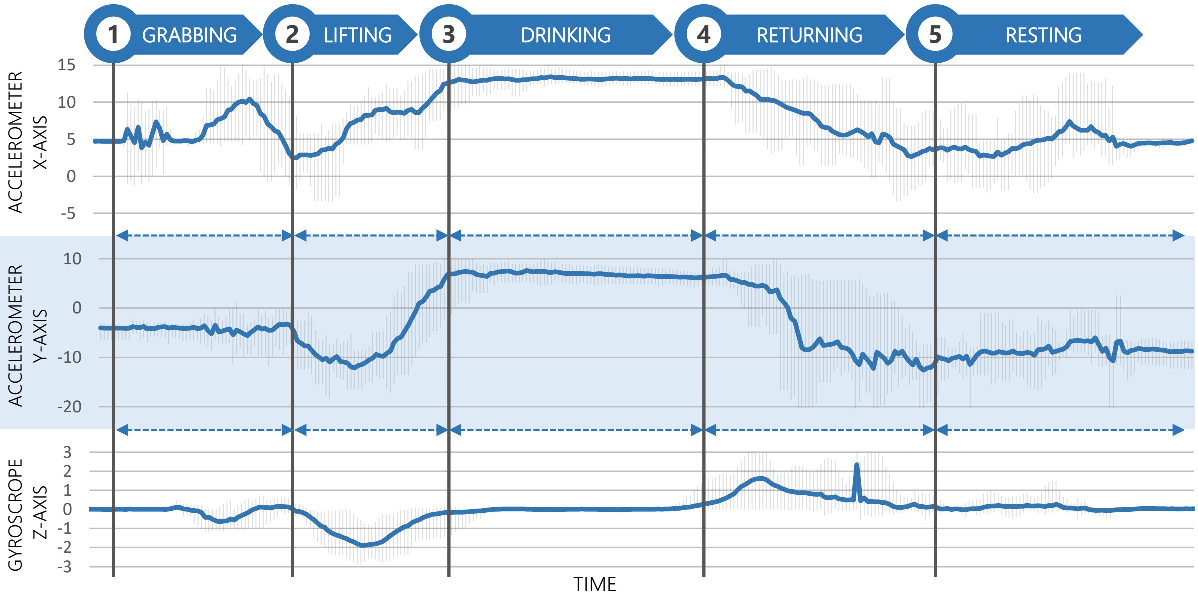


Figure 41. Plot of sensor data for drinking recognition

Afterward, the drinking begins (3), and the values of the sensors do not change significantly. The length of this phase correlates with the amount of the consumed beverage, but due to very different vessels and drinking patterns, we have limited ourselves to the drinking frequency. In phase (4), the vessel is put down, reversing the second phase with a little more attention. The deviation of the drinking samples increases since the last drinking phase time varied (top, middle, and bottom). Finally, the hand returns to a lying position at the table (5), showing an x-axis acceleration (top) without significant acceleration and rotation peaks on the other axis (middle and bottom).s

This sequence can be detected rule-based within the live data, but the determined parameters merely work for one person. Therefore, we amplify our procedure with a machine learning approach. Each user can train a personalized drinking motion, which enables an individually tuned recognition. We transform parts of the actual data into a characteristic feature vector and utilize a support vector machine (Cortes / Vapnik 1995) to classify the sequence for a drinking motion, including all axis of the accelerometer and gyroscope. To implement the SVM component in the *healthWatch* smartwatch application, we rely on the *LIBSVM* library (Chang / Lin 2011) that provides a *Java*-based programming interface. This procedure provides a satisfying accuracy detecting and counting drinking motions automatically through smartwatch sensors and does not exceed the computational capabilities of a smartwatch.

Figure 42. Screenshots of *healthWatch* smartwatch application

Dashboard. After logging in for the first time, users receive a short onboarding session in which the web application's primary functions are presented. On the dashboard of the web application (see Figure 44) as well as in the smartwatch application (see Figure 42), the collected vital data is displayed to the employee [»R_{F5}]. Accordingly, pulse, steps, and drinking frequency are visible [»R_{F2}]. Besides, users can also specify their emotional state [»R_{F4}] via the system by setting their mood. This is determined by employing five emoticons, ranging from *angry* / *sad*, over *neutral*, to *satisfied* / *happy*. The mood functions are an additional mental health indicator available to health managers in an aggregated form. In this way, departments with a higher level of discomfort (e.g., due to stress) can be identified so that appropriate organizational interventions can be implemented.

The dashboard of the web component also provides a graphical and statistical presentation of the progress of vital data over time and highlights trends [»R_{F5}]. The view can be adjusted as desired using filters and include an evaluation note so that users can objectively assess their health status even without medical experience [»R_{M4}]. Moreover, the system notifies the user about sudden changes and reminds them of healthy habits [»R_{F3}].

Besides, the dashboard provides an overview of upcoming courses as well as daily challenges and team quests to guide users through health-promoting activities[»R_{F8}]. Thus, the quests fulfill a goal-setting function for users and are categorized according to the three vital parameters (pulse, footsteps, drinking). To ensure that the objectives do not over- or under challenge a heterogeneous user group, the difficulty of quests is adapted based on the tracked vital data [»R_{M5}]. Specifically, the activities of the last five days are considered to generate a challenge that is slightly above the data average and thus achievable for users until they have reached a set limit. Thus, we draw upon the Fogg Behavior Model (FBM, see Figure 43) to sustainably improve the employees' health **behavior** (B) (Fogg 2009):

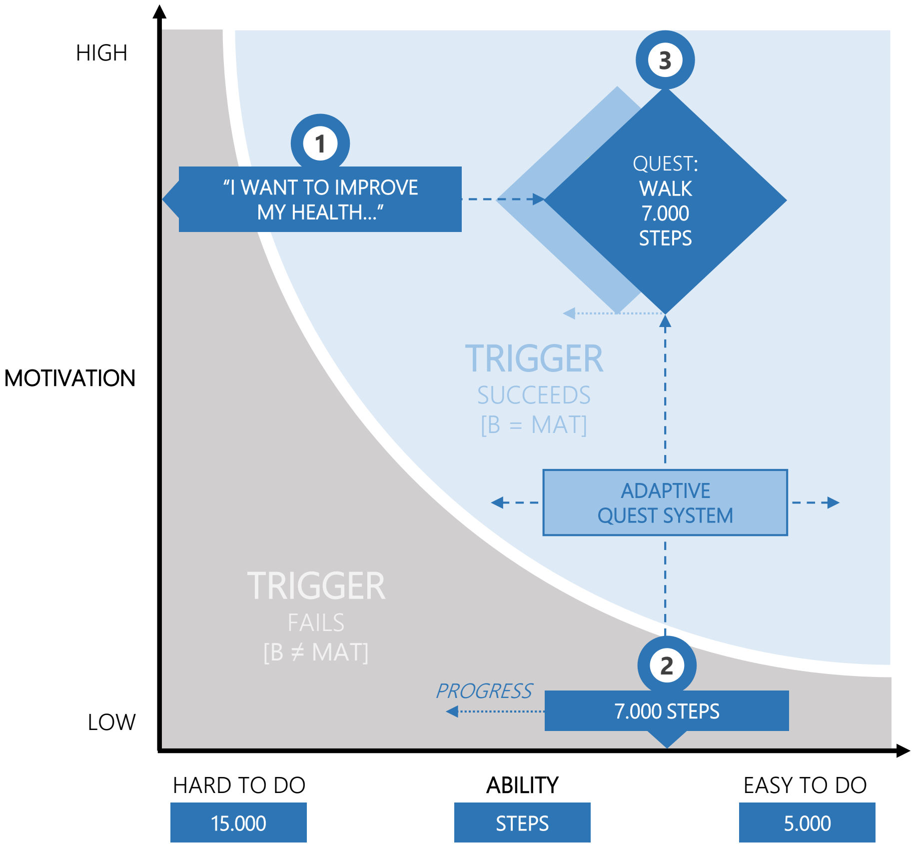


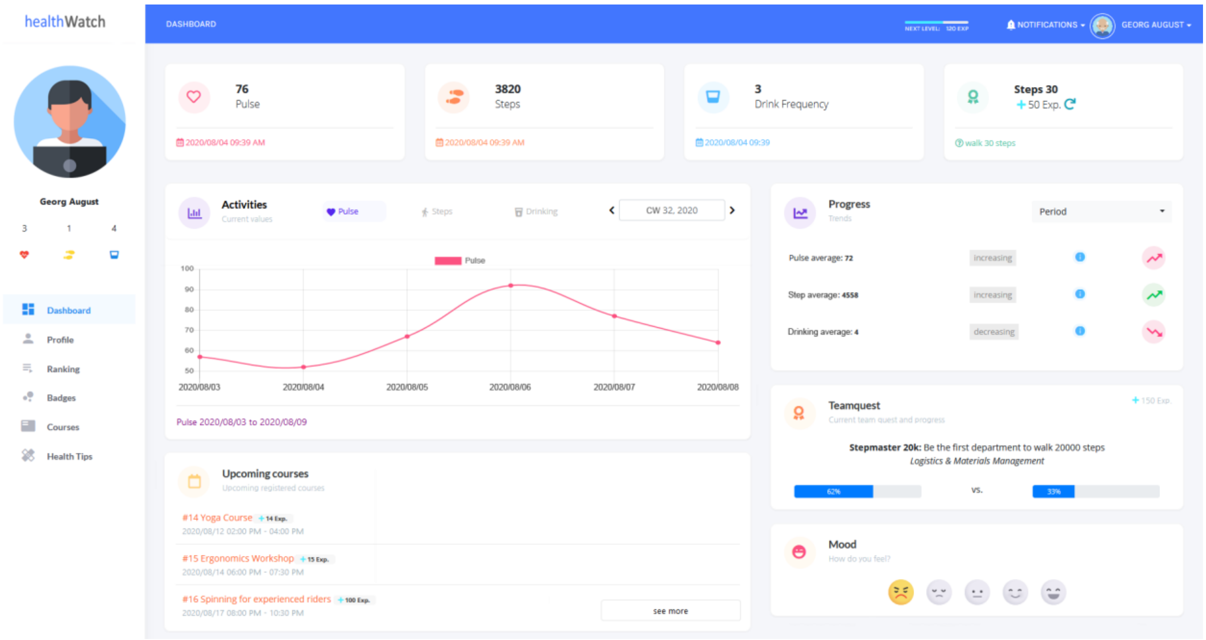
Figure 43. FBM with adaptive quest system

1. **Motivation** (M): We assume that users, in general, are sufficiently motivated to improve their state of health – otherwise, they would not freely use the application. Playful interventions also supplement the inherent interest in the own health to promote fun and thus motivation.
2. **Ability** (A): The users differ in terms of their health and physical conditions so that their abilities will vary in terms of dealing with health-promoting activities. Consequently, our adaptive approach ensures that the offered quests have appropriate difficulty levels and support users to experience positive progress in the long-term.
3. **Trigger** (T): The daily quests act as the trigger to encourage users' health-promoting behavior. Changing challenges allow users to improve in different categories continuously. Reminding notifications and progress feedback support users to complete quests and thus maintain behavior.

Profile. Apart from the central dashboard, the system provides (public) profile pages for each user. The profile contains the user's contact details and further information, such as the department. Thereby, the users of the application can interact with each other [»***R**$_{M6}$*]. Specific vital data is not visible to protect health privacy [»***R**$_{M3}$*]. Instead, only the achieved user levels for pulse, steps, and drinking are shown to reflect the user's health activity, but not the actual health status. The progress bar also shows how many points users need to collect before reaching the next level (see Figure 46). Moreover, the numbers of badges collected, courses attended, and profile likes received (from other users) are displayed, which also serve as activity metrics [»$\boldsymbol{R}_{M4}$].

Within the profile, users can also set various preferences to personalize the application [»$\boldsymbol{R}_{M2}$]. On the one hand, users can set *quest preferences* by choosing whether they want to receive pulse, step, or drink related quests. On the other hand, *profile preferences* can be set that affect the public visibility of single parts of the profile (such as levels or likes) or the entire profile. Furthermore, users can choose to participate – and thus be visible – in the public leaderboard for each category or customize their avatar. This way, we also want to consider the assumption of different player types / traits and their respective preferences when using a gamified application (Tondello / Nacke 2019).

The self-assessment is another feature within the profile. This function is called after the initial login during the onboarding phase to compensate for the missing dataset for the adaptive quest system. Therefore, the users can assess their health status regarding the three vital parameters of pulse, steps, and drink frequency [»$\boldsymbol{R}_{F4}$]. As impairments of the users' fitness can occur during everyday life, e.g., due to accidents or injuries, it is possible to continuously update the self-assessment and align it with the users' current needs [»$\boldsymbol{R}_{M2}$].



Stepmaster 20k: Be the first department to walk 20000 steps
Logistics & Materials Management

#14 Yoga Course +14 Exp.
2020/08/12 02:00 PM - 04:00 PM

#15 Ergonomics Workshop +15 Exp.
2020/08/14 06:00 PM - 07:30 PM

#16 Spinning for experienced riders +100 Exp.
2020/08/17 08:00 PM - 10:30 PM

Figure 44. The dashboard of *healthWatch* web application

Tips and courses. Contentwise, the application offers users health tips [»$\boldsymbol{R}_{F9}$] and courses [»$\boldsymbol{R}_{F8}$] to enable employees to increase their health competence. The health tips are tailored based on the vital data collected in the previous week. In addition to some general health tips, which for example, refer to an ergonomic workplace, the user therefore also receives specific tips against stress, lack of exercise, or dehydration. The educational multimedia content is provided in the form of micro-content (Decker et al. 2015) so that employees can learn in short breaks. Because of the web application, content such as externally produced videos or additional literature like scientific articles can also be referenced.

Furthermore, employees can use the central platform to find health courses [»$\boldsymbol{R_{F8}}$]. This way, the information system can be used as the primary communication tool within CHM to advertise specific course offers across departments and, at the same time, determine the demand in advance. To lower the participation hurdle, users can directly register with a single click for a course via the platform and avoid filling out forms or contacting the trainer or teacher.

Gamification. The information system's core functions and features are supplemented by individual game elements in the sense of a gamification approach to promoting the users' basic psychological needs concerning autonomy, competence, and relatedness. For this purpose, we use the mechanics-dynamics-aesthetics (MDA) framework postulated by Hunicke et al. (2004) to address the three psychological needs from SDT. Based on the MDA framework, we theoretically deduced several causal chains of common game design elements (Sailer et al. 2017; Thiebes et al. 2014; cf. Blohm / Leimeister 2013) that support need satisfaction. As a result, we elaborated the following conceptual model (see Figure 45):

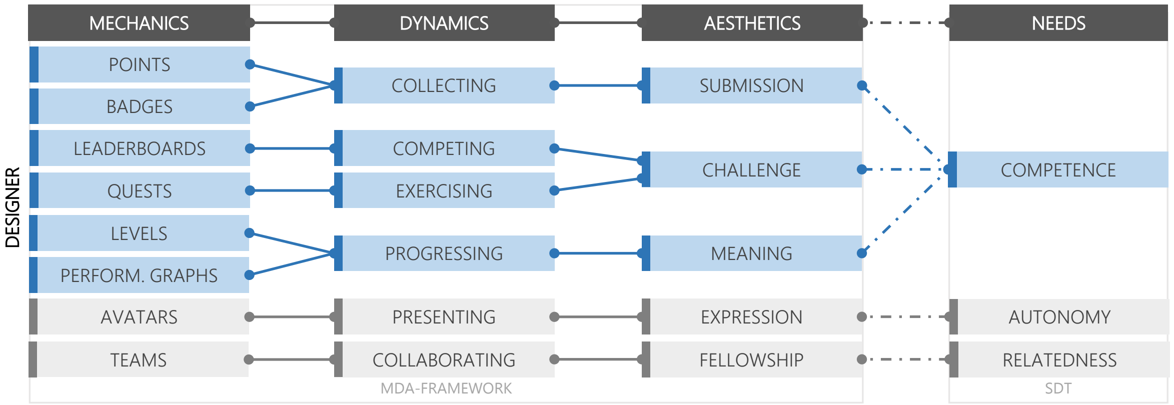


Figure 45. Conceptual model for implementing gamification in *healthWatch*

Points: In gamified applications, the mechanic *points* represent a basic unit to record the user's score and determine a winner (Sailer et al. 2017). Points represent a simplified form of feedback and are usually required for other mechanics (e.g., leaderboards or levels) (Werbach / Hunter 2012). In our prototype, we refer to the respective form of user experience points (EXP) (Zichermann / Cunningham 2011), which are collected when completing a quest, achieving a badge, or attending a course [»$\boldsymbol{R_{M4}}$].

Badges: The mechanic *badge* is a visual reward that users receive for certain activities or the achievement of goals. Our prototype implements badges as a possible form of feedback [»$\boldsymbol{R_{M4}}$], but also as a goal-setting [»$\boldsymbol{R_{M5}}$] function for health-promoting achievements (Sailer et al. 2017).

Quests: The mechanic *quest* provides the user with a task that can be completed and thus sets a goal (Zichermann / Cunningham 2011). In our context, the adaptive quests are supposed to evoke specific health-promoting dynamics, such as exercising [»$\boldsymbol{R_{M5}}$].

Levels: The mechanic *level* documents the skills, expertise, or experience a user has acquired or demonstrated over time within the gamified application (Thiebes et al. 2014). We use levels as a feedback element to show how many experience points a user has acquired in the three vital parameter categories of pulse, steps, and drink frequency [»$\boldsymbol{R_{M4}}$].

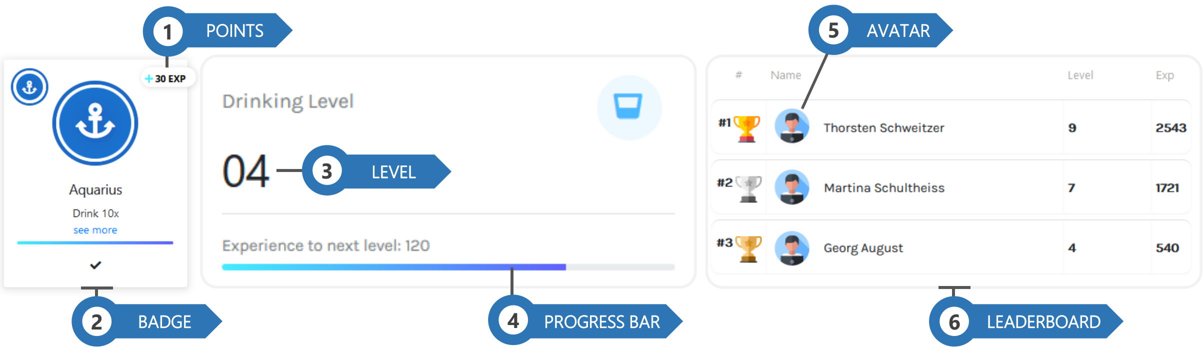
Performance graphs: The mechanic *performance graph* shows users' performance or progress in intra-individual comparison over a certain period. A very simplified representation of a performance graph is the progress bar. These charts fulfill a feedback function [»$\boldsymbol{R_{M4}}$] that has a positive effect on the experience of competence (Sailer et al. 2017). We implemented a performance graph in our prototype in the dashboard to show the user's health development based on the tracked health data [»$\boldsymbol{R_{F5}}$].

Leaderboards: The mechanic *leaderboard* refers to a list of users sorted according to specific criteria (Sailer et al. 2017). For our prototype, we implemented the variant of a no-disincentive leaderboard, where users can only see some competitors below and above them [»$\boldsymbol{R_{M4}}$] (Zichermann / Cunningham 2011). This is intended to prevent users' experience of competence from being negatively influenced by a low ranking position (Wesseloh et al. 2020a).

Avatars: The mechanic *avatar* is a visual representation of the user, for example, an adjustable profile image or an animated character (Sailer et al. 2017; Werbach / Hunter 2012). In our application, users can freely choose or adapt their avatar in order to help identify with their virtual selves and to promote autonomy [»$\boldsymbol{R_{M2}}$].

Teams: The mechanic *team* represents a group of users who collaborate on a particular task or goal, e.g., a quest (Werbach / Hunter 2012). We have implemented this mechanic so that organizational constellations, such as different departments, can also compete against each other and thus experience a stronger feeling of social relatedness within their company [»$\boldsymbol{R_{M6}}$].

Figure 46 visualizes a selection of implemented game mechanics in *healthWatch*, which are found in the user's profile page or the system-wide ranking page.



#	Name	Level	Exp
#1	Thorsten Schweitzer	9	2543
#2	Martina Schultheiss	7	1721
#3	Georg August	4	540

Figure 46. Implemented game mechanics in *healthWatch*

After the features for users have been described, we briefly introduce the functions for other stakeholders. The following **functions** of *healthWatc*h are implemented for **corporate health management** or the **technical administration** and are described subsequently.

Monitoring health data. After logging in, the corporate health managers have access to features in the web application with which they can analyze the occurring data [»$\boldsymbol{R_{F7}}$]. The persons in charge can view the average values of the vital parameters via the dashboard, which are differentiated by the corresponding department. The data is visualized in different charts and can be filtered by time, departments, or vital parameters. Moreover, the progress is shown in trends, and critical key figures are highlighted. This way, the corporate health management obtains a rough overview of the health status of the respective departments without affecting the privacy of the individual employee [»$\boldsymbol{R_{M3}}$]. The general health status of a company allows deriving other targeted health-promoting interventions.

Content creation. The web application also enables the persons responsible for CHM to provide content for employees [»$\boldsymbol{R_{F9}}$]. The underlying content management system enables the manager to create and maintain all kinds of content on the platform. Specifically, the health manager can administrate course offers [»$\boldsymbol{R_{F8}}$] and create health tips and advice via a simple editor. Furthermore, they can adjust the playful elements such as (team) quests or add new badges to the system for the different vital parameters and their combinations. This way, the corporate health management can plan and control health-promoting activities and share them in the company.

Role and user management. In order to protect the health data of employees, we have developed an appropriate role and user management system that controls the privileges of individual users [»$\boldsymbol{R_{F6}}$]. In principle, each user receives personalized access to the application and is assigned to a department and a role. Depending on the role, they then receive different read (or write) rights. On the one side, normal users only have the right to view their health data [»$\boldsymbol{R_{F5}}$]. On the other side, superiors or employees who belong to the CHM can only view the aggregated, anonymized data of their respective department [»$\boldsymbol{R_{F7}}$].

Figure 47 summarizes the required functionalities in a UML use case diagram. The features marked with a smartwatch symbol are also available in the smartwatch application. Additionally, we added a short identifier to indicate the underlying functional (F_X) or motivational (M_X) requirement for each feature.

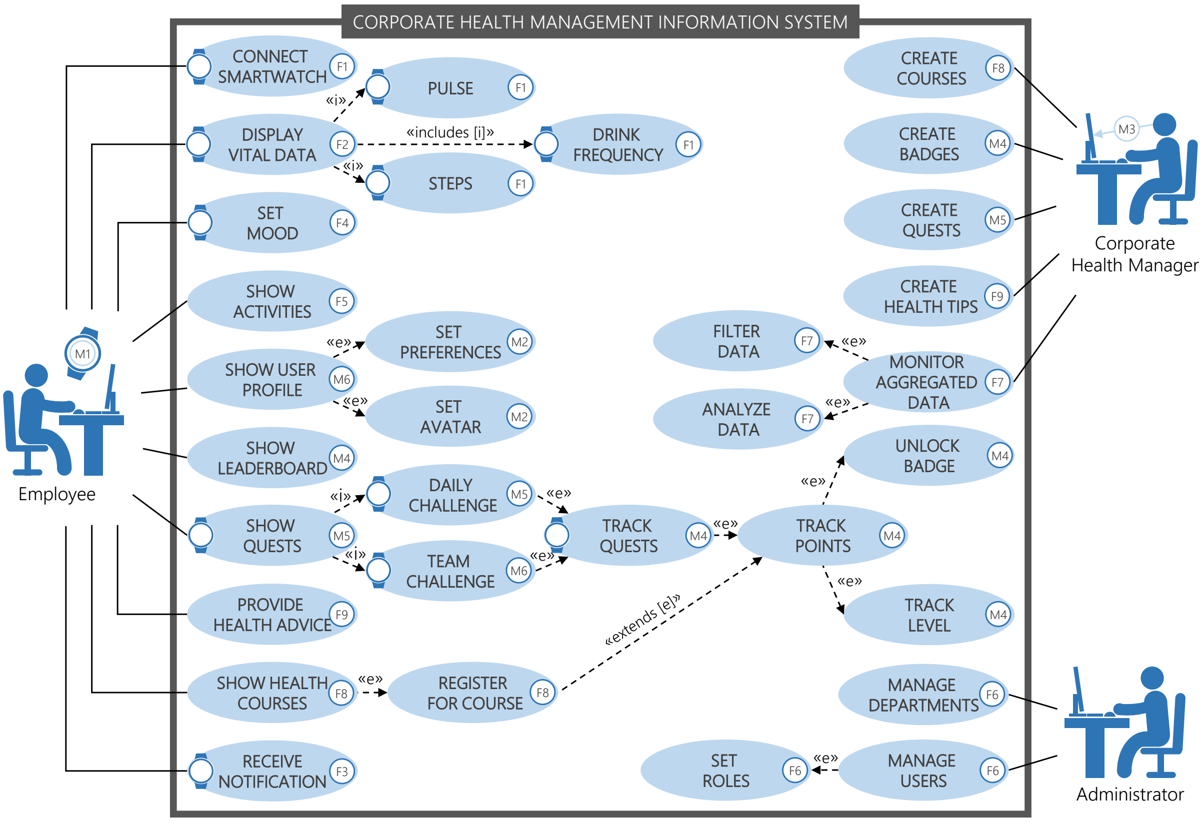


Figure 47. UML use case diagram of *healthWatch*

5.4.4 Demonstration

To initially introduce *healthWatch* to domain experts after the design and implementation phase, we conducted a two-fold demonstration according to our research process (see Figure 39). For this purpose, we first organized a live presentation involving decision-makers in various positions representing different perspectives of corporate health management related practice. This includes the department head of the health management department of a health insurance company, the corporate health management department head of a university-related hospital, the head of a university sports department, and a team leader in the domain of movement-related health promotion at a university. We configured the software to fit a realistic scenario for employees at office workplaces and ran through the employee's and health manager's roles, respectively, to visualize the participation and management perspectives supported by the system. This way, we demonstrated our idea to implement smartwatches as a ubiquitous and unobtrusive health sensor and gamification elements to foster employees' motivation with a pragmatically and easily understandable prototype.

Subsequently to the narrow circle of domain experts from the seniority level, we broadened the group of participants and included employees at various office workplaces and companies. In total, we demonstrated *healthWatch* to 33 employees. For that, we engaged volunteering research associates of a university chair of application systems, employees of the administration of a university, employees of university secretariats, employees supporting digital education and electronic examinations at a university, employees of the student administration of a university, and an IT department of a medium-sized company. They differ highly in their professional backgrounds, and merely a small part exhibits business-related IT knowledge. The ages of the participating employees are equally distributed between approximately 25 and 50. All participants have decent years of work experience (> 2 years) and an understanding of the health-related issues at their office workplace.

Since the smartwatch in our concept is merely utilized as a sensor to gather the required health data and display key figures and notifications, we focused on the concept of *healthWatch* that can mainly be represented by the web-based component during the demonstration. After a short introduction, the participants are asked to log in to *healthWatch* and are guided through the system by the animated onboarding procedure. Once the tutorial that introduces all main functionalities with a small instruction has been completed, the participants were free to explore the system and test all sections as long they would like to.

5.4.5 Evaluation

In order to evaluate employees' attitudes concerning the concept to support corporate health promotion utilizing smartwatches and gamification elements digitally, we conducted an evaluation study composed of an online questionnaire. For that, the 29 participants of the online demonstration are requested to fill in a qualitative and quantitative online survey after becoming familiar with the system.

Our questionnaire consists of 22 items, including five qualitative questions. The quantitative items were tested on a 7-point Likert scale (strongly disagree [1] – strongly agree [7]). The online survey was divided into four thematic blocks:

1. In the first block, the affinity of the participants for IT systems and smartwatches was questioned, and they were asked to assess the potential of these tools for health management.
2. In the second block, the participants were asked about the usefulness of the implemented features.
3. The third block focused on the individual, motivational effect of the different features of *healthWatch*.
4. In the fourth block, questions about acceptance, the intention of use, and satisfaction of basic needs in the context of intrinsic motivation were asked.

For the last block, we combined validated items from the Technology Acceptance Model (TAM) by Davis (1989) and the Intrinsic Motivation Inventory (IMI) by Deci et al. (1994) for our purposes. The complete, translated questionnaire structure can be found in Table 35 of appendix 0.

The survey results in the first block show that even though the participants like to deal with technical systems in more detail (M = 5.07), they yet have little experience in using smartwatches (M = 2.62). The idea of supporting corporate health management with smartwatches is viewed neutrally by the participants (M = 4.55). Furthermore, the passive collection of data via sensors (M = 3.72) and the importance of digital support for health behavior (M = 3.83) is viewed rather skeptically by the surveyed employees.

The qualitative answers help to explain the mixed opinions about the idea of promoting corporate health with smartwatches. On the one hand, the surveyed employees mentioned various advantages, e.g., in the incidental tracking of data (38 % of participants), the objective data source (28 %) or the incentives or awareness for the topic of health promotion (21 %), as the following quotes point out:

> *"An incidental tracking and the presentation of health data make it easier to establish personal health management" – Employee 21.*
>
> *"Exact overview of what has actually been done […]. One likes to under- or overestimate their own performance" – Employee 8.*
>
> *"The ability to motivate or remind the user to do something […]" – Employee 2.*

On the other hand, however, their answers also show a general lack of trust in a digital solution for corporate health management. We found a few reasons by looking at possible concerns the participants mentioned. A large proportion (62 %) of respondents expresses concerns about data protection or data security, as the following exemplary quotes show:

> *"Collecting and providing very personal health information to others may raise privacy concerns" – Employee 28.*
>
> *"Data protection: What happens with the collected data? What is it used for? Who has access?" – Employee 23.*
>
> *"Data security: What happens with my data, who has access, and what are the consequences?" – Employee 8.*

Besides, a considerable number of participants (44 %) fear pressure from the employer, as the company could monitor or control them when wearing the smartwatch:

> *"My employer monitors me and my colleagues." – Employee 18.*
>
> *"If it is in the corporate context, it could represent a feeling of being controlled and surveilled." – Employee 9.*

Some employees simply refuse to disclose highly sensitive health data to the employer or do not consider it as a benefit. Moreover, a few participants believe it will rather be disadvantageous for employees, as the following quotes illustrate:

> *“My health status is not the employer’s concern.” – Employee 12.*
>
> *“I am not very affine towards this and would rather keep the data private than share it with my employer.” – Employee 5.*
>
> *“I do actually not see the need for [health] comparisons with my other colleagues.” – Employee 11.*
>
> *“…job-related disadvantages based on health data.” – Employee 20.*

In the second block, participants evaluated the functionality of the information system. Using a matrix query, individual features were evaluated concerning their usefulness. The employees see the most significant benefit in the provided dashboard (M = 6.24), providing a corresponding overview of other functionalities. Furthermore, users find the provided step data (M = 5.83), notifications (M = 5.62), the onboarding process (M = 5.41), and the course offers and health tips (M = 5.17) to be most useful. The presentation of the two other vital parameters, pulse (M = 5.00) and drinking frequency (M = 4.79), is regarded as slightly less useful compared to step data. The respondents see the least benefit in the functions with which they can assess their health status (M = 3.62) or indicate their current mood (M = 3.10). On average, however, the system is considered to be rather useful (M = 4.98). The qualitative feedback on the most popular three functions supports these findings. The responses furthermore indicate that the information system mostly met the respondents’ expectations concerning its implemented functions, e.g., the step data or the health tips. Even our approach to track a drinking movement was appreciated, as the following quotes highlight:

> *“Drinking frequency, because until now I did not know that this could be tracked with a smartwatch sensor” – Employee 8.*
>
> *“Information about fluid intake, because I tend to have problems there." – Employee 11.*

In the third block, the features were evaluated with regard to their motivational effect. On average, the system is not perceived to be very motivating (M = 3.70). The respondents rated the performance graphs as having the highest motivational effect (M = 4.79), followed by the daily quests (M = 4.46). A mixed result is shown for the team quests (M = 3.93.) as well as for the points and levels mechanic (M = 3.76). On average, the employees rated the leaderboard as well as the badges as rather less motivating (M = 3.52). According to the survey results, however, the public profile (M = 2.90) and the customizable avatars (2.69) have the least motivational effect. The game elements’ motivational effects are particularly considerable for their partially distinct bimodal distribution. For example, the respondents tended to give rather extreme answers (either strongly disagreeing [1] or strongly agreeing [7]) for the motivational effect of leaderboards (Mo_1 = 2; Mo_2 = 6), team quests (Mo_1 = 2; Mo_2 = 6) and avatars (Mo_1 = 1; Mo_2 = 5).

Figure 48 visualizes both user feedback results in case of the feature's usefulness and motivational effect in a box plot. Furthermore, the descriptive statistics can be found in Table 36 and Table 37 of appendix 0.

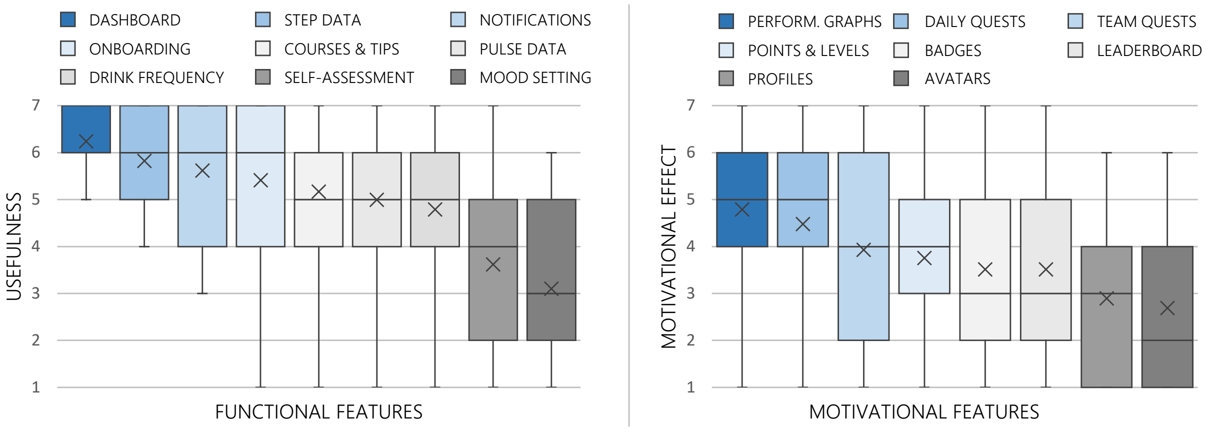


Figure 48. User's average rating of features considering usefulness and motivational effect

The qualitative feedback also gave us some insights into the critical factors of the concept. The employees were particularly critical about the public profile, as it puts pressure on the user and raises privacy concerns:

> *"I see public profiles in the area of health basically critically" – Employee 20.*
>
> *"Rankings & public profiles promote the (negative) pressure to be 'perfect' […]" – Employee 16.*

Besides, individual game elements were also viewed skeptically, as they could distract from the actual work assignments, for example:

> *"Team quests might take too much time and distract from work tasks" – Employee 23.*

Furthermore, the feedback showed that the purpose of individual functions was not always comprehensible. Some respondents questioned the self-assessment in particular:

> *"Self-assessments are pointless" – Employee 21.*
>
> *"Unclear what the self-assessment refers to: Right now? Today? In general?" – Employee 16.*

Moreover, the tracking of the drinking frequency raised questions among a few participants, for example:

> *"Will you get a badge if you drink beer instead of water?" – Employee 1.*
>
> *"The drinking frequency seems strange to me. I understand that a smartwatch only records the frequency of drinking (although I wonder how accurate that is), but many would consider the volume of water consumed more important. I am therefore unsure if and to what extent the drinking frequency is a useful indicator" – Employee 7.*

Besides the criticism, many users also expressed themselves positively about the system compared to conventional fitness trackers. Especially the playful feedback and incentive elements were highlighted:

> *"It is more fun to get familiar with the system. If you like the competition, you will be motivated to challenge yourself and also have an entertaining topic to talk about during the lunch break" – Employee 14.*
>
> *"For teams or for people who like to create something playfully, such a system would fit well because it could create an incentive. Daily goals and health tips, as well as the ranking list, cannot be found within a conventional fitness tracker" – Employee 19.*

Overall, the users also like the individualized information offers and the fact that the smartwatch is the only device for collecting vital data that also supports other functions or use cases.

> *"The linking, of course, offers with own data" – Employee 3.*
>
> *"Greater functionality and flexibility. Only one device needed" – Employee 21.*

In the last block, the participants answered questions regarding the satisfaction of psychological needs for autonomy, competence, and relatedness. Besides, questions were asked about aspects of interest and entertainment, and the perception of the system. The results of this psychological, self-reported feedback show, on average, a slightly positive assessment (M = 4.20). The participants rated the use of the system as entertaining (M = 4.79) and partly agreed that it would be interesting for them to use it (M = 4.45). In particular, they rated the feedback from the system as informative (M = 5.45). They also partly assume that the system can promote their health competence (M = 4.38) and satisfaction with their health state (M = 4.24). In terms of autonomy, employees do consider voluntary participation (M = 4.28), even if they feel a little pressure during the system's use (M = 4.38). The system itself is also perceived as being slightly surveilling (M = 4.71). Otherwise, respondents tend to reject collaborative group activities via the platform (M = 3.41). They also do not assume that they would feel more connected to their colleagues when using the system (M = 3.66).

Figure 49 shows the results of the last question block as a box plot.

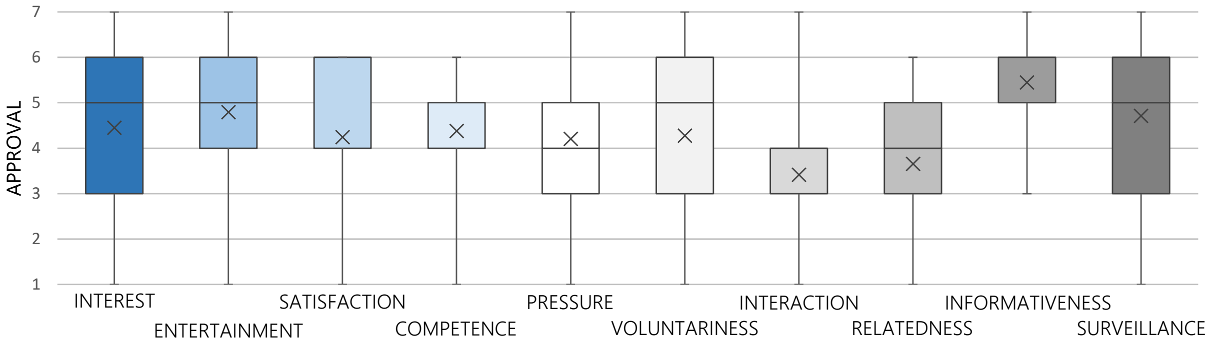


Figure 49. User's average approval for psychological aspects of usage

5.5 Discussion and Implications

After presenting the design of *healthWatch,* including the evaluation results, we now analyze and discuss our findings to provide implications for research and practice. First of all, the participants in the study have agreed on several advantages of using smartwatches in corporate health management and see the potential for use in daily life. Overall, employees approve an overview of their health values in a dashboard or notifications displayed on the smartwatch. However, the compendium of health knowledge within the information system, such as health tips and health courses, was appreciated in our survey, as it creates health awareness and sensitizes for particular topics. On a motivational level, the performance graphs, which document personal progress and thus enable detailed feedback, were compelling. But also quest functions contribute positively through their goal-setting function to do something for health. We imply that a useful tool for enterprise health promotion that provides necessary health information, tips and course offers, feedback, and goal-setting functions, already provides additional value for most employees.

However, the survey results also reveal that the topic of health promotion does not appeal to everyone. For example, some employees at the moment have no health deficits and therefore do not see any additional value of such a system. Others believe that the system only creates benefits for those whose inherent interest in their health is lacking:

> *"For people who have problems taking care of their health, a system for health promotion can be helpful" – Employee 14.*
>
> *"Probably only motivates people who do not pay attention to a healthy lifestyle for their own good" – Employee 22*

Therefore, we assume that younger employees, in particular, are less interested in digital health promotion measures, even though they are likely to be much more affine towards smartwatches on average than older employees. Therefore, it would be helpful to include an assessment of the employees’ state of health and age in future research when evaluating health promotion approaches.

The most significant concern about using a digital system, especially smartwatches, for health promotion manifests itself in data protection and surveillance. The results of the survey confirm the importance of privacy, as Kaiser / Matusiewicz (2018) already observed. Despite our existing system architecture, which provides a technical solution to ensure user anonymity, respondents expressed a sense of surveillance. We suppose that this is also why features such as the mood-setting or the self-assessment were rated to be less useful from the employees’ point of view, as they are just another way of collecting data that make them even more transparent to the employer. As these factors have a significant impact on the success of such a system, the question arises of how these issues can be addressed. We, therefore, elaborated two approaches to overcome the privacy-related concerns:

1. Personal data could be stored exclusively on the smartwatch and transferred to the server in an aggregated form to ensure anonymity in the technical domain. Since the smartwatch can also be worn privately, an "out-of-office" function might also reduce privacy issues.
2. From an organizational perspective, employees should be involved throughout the early stages of the system’s introduction. In particular, it should be explained which data is collected, how and to what extent it is processed, and why it is beneficial to the employee. A confirmation that the use of the information system is voluntary and that it primarily remains an offer for employees could strengthen trust and acceptance.

In conclusion, we draw the implication that a clear privacy concept is a critical success factor for introducing digital health promotion programs in the enterprise context.

Also, the evaluation showed that the implemented game elements were perceived ambivalently by the respondents. Opinions are particularly oppositional when it comes to avatars, team quests, and rankings: while some attribute them a high motivational effect, others perceive them to be less motivating. For example, a “health competition” induced by leaderboards seems undesirable for some employees, as they feel exposed to additional pressure. In turn, others express privacy concerns, as this form of interaction can allow colleagues to have insights into their state of health or commitment. Another reason for declining game elements, such as avatars, is that they may distract from the actual work. There are concerns that game elements could make employees primarily pursuing their daily health goals instead of completing their daily work tasks. Based on these results, we imply the importance of considering the different user preferences for game design elements when implementing gamification in corporate health promotion.

All in all, it has been shown that the technological design of an information system for workplace health promotion is just one of the critical success factors. Equally important is the organizational integration into the company and transparent communication with the employees. Besides, to involve the target group in the introduction process at an early stage, companies have to create the prerequisites and a beneficial working atmosphere within employees to promote their health. For example, particular timeslots during the workday can be defined in which employees can pursue their personal health goals enabling freedom and reduce pressure.

5.6 Conclusion and Outlook

In this paper, we addressed the digital support of workplace health promotion with a smartwatch-based and gamified information system for employees at office workplaces. For that, we designed, implemented, and evaluated the software prototype *healthWatch* applying a research design inspired by the design science research methodology (Peffers et al. 2007). We first described the corporate health scenario found in practice, including employees at office workplaces, a corporate health manager, and a technical administrator. Based on a literature review, we formulated objectives and inferred requirements for a subsequent development process addressing RQ1. We designed and implemented a *Wear OS* smartwatch application, a web-based backend, and a server architecture building the *healthWatch* information system. A broad range of companies can apply the software prototype since it uses standard technologies and is easily configurable. We evaluated the software during the concluding step, validated its utility with 29 employees working at different office workplaces, and addressed RQ2. According to the experts, the unique characteristics of smartwatches and elements from the domain of gamification can facilitate digital systems that support corporate health management. Additionally, some critical factors were mentioned.

The evaluation results reveal a mixed perception of the application’s potential users. On the one hand, the employees recognize the various advantages of a digital solution based on a smartwatch. On the other hand, they also express their concerns about data privacy and surveillance by the employer. Nevertheless, most respondents still regard our system to be widely useful. In terms of motivational effectiveness, however, the results remain less meaningful. We assume that this is mainly due to the uncertainty regarding privacy in *healthWatch,* as we did not sufficiently inform the participants about the systems’ strict privacy policy to ensure sufficient transparency. In particular, an explanation of which health data is available to superiors or health managers was not discussed during the laboratory experiment. Since we do not intend to transfer any individual health data to corporate health managers or superiors that would allow backtracking, we estimate that the actual interest to use the system is potentially higher. We sincerely want the system to be regarded as a supporting and motivating information system for employees and not as a health surveillance tool for companies. However, in order to establish a goal-oriented health promotion program at office workplaces, we also believe that corporate health managers need to know about the staff’s general state of health. Therefore, our system also provides aggregated and anonymized key figures that should not be disadvantageous for individuals but helpful when implementing other health-promoting interventions. To counteract privacy and surveillance concerns, we recommend involving the employees, the works doctor, and the work council in the early stages of the integration process to negotiate appropriate and transparent agreements.

As usual for practice-oriented research studies, there are methodical limitations. First, the empirical foundation of the requirements within the design phase is merely based on literature and experience inside a university scenario. We plan to test and evaluate *healthWatch* to a much greater extent, including a more significant range of companies during our future research and amplifying the software to overcome this limitation. However, the presented evaluation verified that the combination of smartwatches and gamification to create a novel information system could support the corporate health promotion and exhibits utility for the employees and employers. Since the participants indicated that they had just a little experience with smartwatches, we take novelty effects due to high interest into account and may repeat the questionnaire after some time of experience. Second, our evaluation is limited as the participants could only test the web-based component for a small time-frame during the online evaluation and got merely little information about the concept’s details. They were not able to test the whole system, including the smartwatch, at their workplace yet. Hence, a long-term evaluation, including a higher number of participating employees who can test the system in their daily lives, can be considered in future studies.

Besides additional studies, we would like to extend the functionality of *healthWatch*. We implemented basic measures indicating the health status and well-being of an employee. On the one hand, we would like to enhance the current features and elaborate on further gestures correlated to health such as smoking or eating. On the other hand, smartwatches offer counting sensors. Ambient light sensors can alert employees to ill light conditions for their eyes. Contact sensors can register the temperature and lead to a better working environment when the employees in the office suffer from heat or cold. Finally, microphones can be utilized to detect noise stress and promote a suitable work atmosphere. Since the basis has already been created, the extensions can be easily integrated into *healthWatch*. The values can be used to make the quests more varied and individual. In the domain of game elements, we would like to revise or replace the bad evaluated ones carefully.

Overall, we created an applicable software solution for the digital support of corporate health promotion. We transferred the popular idea of utilizing health values recorded by wearable devices for health promotion in the private domain by fitness tracker and native smartwatch functions to the corporate sector and also provide individual assistance for the employees, valuable feedback for a corporate health manager, and an approach to improve the quality of work at office workplaces. However, it does not deviate employees from work and can be used incidentally due to smartwatches’ unique characteristics. Besides, it motivates employees in the long-term to participate in a health promotion program because of gamification. During the design progress, we gathered insights about how to combine smartwatches and gamification into a novel information system and contributed a conception approach with design guidelines.

III Usability of Smartwatch-based Information Systems

This research complex provides a closer look at the topic of usability concerning applications running on smartwatches. As a supporting element for the studies within the first and second research complex, MRQ 3 investigates the usability analysis of smartwatch applications. As depicted in Figure 50, Zenker / Hobert (2020, study 6) refine this superordinate objective and assess (1) the requirements for the analysis of usability on smartwatches with RQ 1, and (2) identify and extend existing methods in a usability framework for smartwatches with RQ 2. Finally, the meta-research question is addressed by the design and development of *usabilityWatch*.

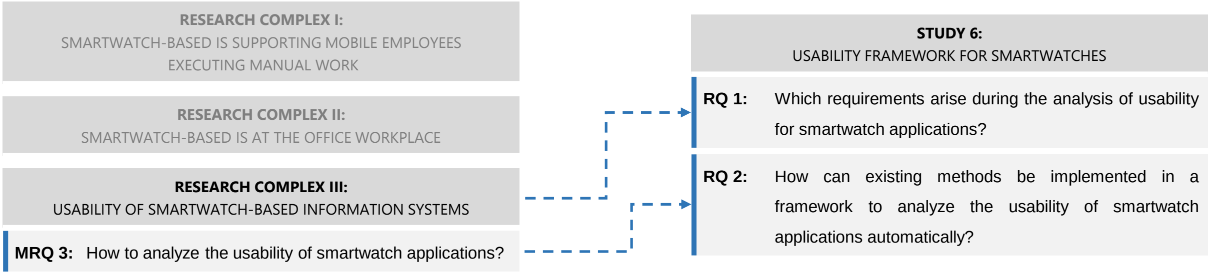
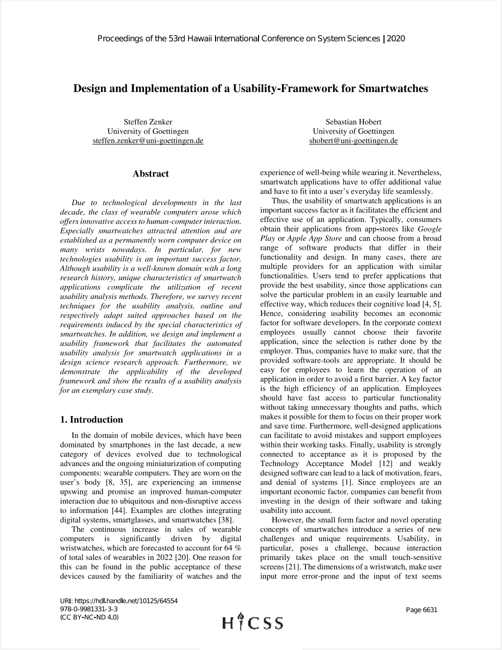


Figure 50. Refinement of the meta-research questions of research complex III

Supplementary material for the study is provided in appendix 7, including the translated questionnaire of study 6.

6 Usability Framework for Smartwatches

Design and Implementation of a Usability-Framework for Smartwatches



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Design and Implementation of a Usability-Framework for Smartwatches

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Abstract

Due to technological developments in the last decade, the class of wearable computers arose which offers innovative access to human-computer interaction. Especially smartwatches attracted attention and are established as a permanently worn computer device on many wrists nowadays. In particular, for new technologies usability is an important success factor. Although usability is a well-known domain with a long research history, unique characteristics of smartwatch applications complicate the utilization of recent usability analysis methods. Therefore, we survey recent techniques for the usability analysis, outline and respectively adapt suited approaches based on the requirements induced by the special characteristics of smartwatches. In addition, we design and implement a usability framework that facilitates the automated usability analysis for smartwatch applications in a design science research approach. Furthermore, we demonstrate the applicability of the developed framework and show the results of a usability analysis for an exemplary case study.

1. Introduction

In the domain of mobile devices, which have been dominated by smartphones in the last decade, a new category of devices evolved due to technological advances and the ongoing miniaturization of computing components: wearable computers. They are worn on the user's body [8, 35], are experiencing an immense upswing and promise an improved human-computer interaction due to ubiquitous and non-disruptive access to information [44]. Examples are clothes integrating digital systems, smartglasses, and smartwatches [38].

The continuous increase in sales of wearable computers is significantly driven by digital wristwatches, which are forecasted to account for 64 % of total sales of wearables in 2022 [20]. One reason for this can be found in the public acceptance of these devices caused by the familiarity of watches and the experience of well-being while wearing it. Nevertheless, smartwatch applications have to offer additional value and have to fit into a user's everyday life seamlessly.

Thus, the usability of smartwatch applications is an important success factor as it facilitates the efficient and effective use of an application. Typically, consumers obtain their applications from app-stores like *Google Play* or *Apple App Store* and can choose from a broad range of software products that differ in their functionality and design. In many cases, there are multiple providers for an application with similar functionalities. Users tend to prefer applications that provide the best usability, since those applications can solve the particular problem in an easily learnable and effective way, which reduces their cognitive load [4, 5]. Hence, considering usability becomes an economic factor for software developers. In the corporate context employees usually cannot choose their favorite application, since the selection is rather done by the employer. Thus, companies have to make sure, that the provided software-tools are appropriate. It should be easy for employees to learn the operation of an application in order to avoid a first barrier. A key factor is the high efficiency of an application. Employees should have fast access to particular functionality without taking unnecessary thoughts and paths, which makes it possible for them to focus on their proper work and save time. Furthermore, well-designed applications can facilitate to avoid mistakes and support employees within their working tasks. Finally, usability is strongly connected to acceptance as it is proposed by the Technology Acceptance Model [12] and weakly designed software can lead to a lack of motivation, fears, and denial of systems [1]. Since employees are an important economic factor, companies can benefit from investing in the design of their software and taking usability into account.

However, the small form factor and novel operating concepts of smartwatches introduce a series of new challenges and unique requirements. Usability, in particular, poses a challenge, because interaction primarily takes place on the small touch-sensitive screens [21]. The dimensions of a wristwatch, make user input more error-prone and the input of text seems

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978-0-9981331-3-3

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Keywords: Software Development for Mobile Devices, the Internet-of-Things, Cyber-Physical Systems, Design, Design Science Research, Smartwatch, Usability

Citation: (Zenker / Hobert 2020, study 6) Zenker, S.; Hobert, S.: Design and Implementation of a Usability-Framework for Smartwatches. In: Proceedings of the 52nd Hawaii International Conference on System Sciences 2020, 6631–6640.

6.1 Introduction

In the domain of mobile devices, which have been dominated by smartphones in the last decade, a new category of devices evolved due to technological advances and the ongoing miniaturization of computing components: wearable computers. They are worn on the user’s body (Billinghurst / Starner 1999; Rawassizadeh et al. 2014), are experiencing an immense upswing, and promise an improved human-computer interaction due to ubiquitous and non-disruptive access to information (Ziegler et al. 2015). Examples are clothes integrating digital systems, smartglasses, and smartwatches (Seneviratne et al. 2017).

The continuous increase in sales of wearable computers is significantly driven by digital wristwatches, which are forecasted to account for 64 % of total sales of wearables in 2022 (Ubrani et al. 2018). One reason for this can be found in the public acceptance of these devices caused by the familiarity of watches and the experience of well-being while wearing them. Nevertheless, smartwatch applications have to offer additional value and have to fit into a user’s everyday life seamlessly.

Thus, the usability of smartwatch applications is an important success factor as it facilitates the efficient and effective use of an application. Typically, consumers obtain their applications from app-stores like *Google Play* or *Apple App Store* and can choose from a broad range of software products that differ in their functionality and design. In many cases, there are multiple providers for an application with similar functionalities. Users tend to prefer applications that provide the best usability since those applications can solve the particular problem in an easily learnable and effective way, which reduces their cognitive load (Apitz et al. 2010; Arning / Ziefle 2010). Hence, considering usability becomes an economic factor for software developers. In the corporate context, employees usually cannot choose their favorite application since the selection is rather made by the employer. Thus, companies have to make sure that the provided software-tools are appropriate. It should be easy for employees to learn the operation of an application in order to avoid the first barrier. A key factor is the high efficiency of an application. Employees should have fast access to particular functionality without taking unnecessary thoughts and paths, which makes it possible for them to focus on their proper work and save time. Furthermore, well-designed applications can facilitate to avoid mistakes and support employees within their working tasks. Finally, usability is strongly connected to acceptance as it is proposed by the Technology Acceptance Model (Davis 1989), and weakly designed software can lead to a lack of motivation, fears, and denial of systems (Acton et al. 2004). Since employees are an important economic factor, companies can benefit from investing in the design of their software and taking usability into account.

However, the small form factor and novel operating concepts of smartwatches introduce a series of new challenges and unique requirements. Usability, in particular, poses a challenge because interaction primarily takes place on small touch-sensitive screens (Kim et al. 2007). The dimensions of a wristwatch make user input more error-prone, and the input of text seems impracticable (Chaparro et al. 2015). In addition, the heterogeneity of smartwatch-devices, including different forms (e.g., round or squared), operating systems, and hardware buttons, necessitates a holistic view on usability analysis.

Gaining knowledge about the usability of smartwatch applications is of immense importance for research and practice. For research, it forms the theoretical foundation for the design of future concepts and possible solutions. For practice, it is possible to create applications and devices with a high level of satisfaction and to conquer market shares.

In order to develop a usability-framework for smartwatches, we apply a design science approach (March / Storey 2008) in this paper. We propose a research design strongly inspired by Peffers et al. (2007), including the problem identification, the deduction of objectives, the design process, and finally, the demonstration and evaluation in order to design a usability framework for smartwatch applications. Overall we address the following research questions:

> **RQ1:** Which requirements arise during the analysis of usability for smartwatch applications?

> **RQ2:** How can existing methods be implemented in a framework to analyze the usability of smartwatch applications automatically?

To answer these research questions, the remainder of this article is structured as follows: First, we present definitions of basic terms introducing the domain of smartwatch applications and usability and outline related research in section 6.2. Second, we describe our research method based on the design science research framework of Peffers et al. (2007) in section 6.3. By applying the research framework to our problem, we illustrate the results of our design science approach in section 6.4. Finally, we discuss our findings and outline our research contributions for theory and practice in section 6.5.

6.2 Theoretical Foundation and Related Research

Since the literature has not focused on usability analysis for smartwatches so far, we survey recent approaches and techniques targeted at mobile systems to gain a holistic view, build a foundation for further considerations and transfer the results to smartwatches. First, we provide definitions for the basic terms and then present the related research.

For a first containment and delimitation of our examination, we sharpen the range of the considered devices. Mobile devices are designed for mobile use and are characterized by high independence of physical locations, accessibility, and localizability (Bv 2013). The devices natively provide connectivity over wireless technologies and are driven by operating systems, which can be extended as required with additional installable and executable applications (Kolbe / Ruch 2014). The span of devices ranges from smartphones and tablets to wearable computers like smartwatches. Mobile applications are special application programs that are designed to run on a mobile device, covering the special characteristics of mobile devices (Masi et al. 2013). A smartwatch is a digital wristwatch extended by a touchscreen and other common computer hardware components, such as a processor, working memory, and battery. In addition, smartwatches provide a wide range of sensors and wireless technologies such as Near Field Communication (NFC), Global Positioning System (GPS), or Bluetooth, as well as a microphone. The interaction with a smartwatch can be done with hardware components, such as the touchscreen, buttons, voice control, or a coupled smartphone. Furthermore, smartwatches are equipped with a hardware-independent operating system, which can be executed on different devices and delimit from other similar devices through the ability to install and execute additional software applications. Not all digital wristwatches, e.g., fitness tracker, meet these criteria and can rather be considered as featurewatches (c.f. featurephones (Kolbe / Ruch 2014)) that provide simple interaction through the coupling with a smartphone (McGrath et al. 2013) and wireless interfaces. The implementation of applications for smartwatches depends on the platform and the operating system and is primarily done natively and fully independent of a smartphone in the platform-specific programming languages (e.g., Java) and the operating system's own Software Development Kit (SDK) accessing the platform-specific hardware and software components over the application programming interface (API).

The user-friendliness or usability of an application can be considered as a quality feature of a product and is defined as intuitive access to the operation of a product in order to accomplish a specific task. Usability is thus understood as a pragmatic quality of software in terms of the achievement of objectives. Usability is defined according to ISO 9241-11 (2018) as the product of (1) effectiveness in the sense of usability for the fulfillment of tasks, (2) efficiency as a measure of the time and effort required to fulfill tasks and (3) satisfaction as a measure for the positive attitude towards the use of the product in a particular context. It has to be distinguished from user experience, which is the users' perception of a system in consideration of the expected utility. In addition, Nielsen (1994) considers the following criteria to play an important role in usability: (1) learnability - how easy can a user learn the operation of an application, (2) memorability - how good can a user operate an application after a certain amount of time without use, and (3) error frequency - how many errors does a user provoke, how serious are these errors and how easily the user can find a solution to resolve the problem.

The mentioned usability attributes can be assigned to the People at the Centre of Mobile Application Development (PACMAD) model (Harrison et al. 2013). The PACMAD model focuses on the usability of a mobile application and identifies the user, the task, and the context as the primary influencing factors for usability. The context got a special role, as the applications are used in different contexts under various influencing conditions. With reference to smartwatches, this factor gets even more important since the devices, concerning their form factor, are used in highly dynamic contexts. Due to this high mobility, including simultaneous or interfering activities and environmental influences, not the full cognitive attention of a user can be presumed as in traditional usability investigations of desktop applications. For this reason, PACMAD uses the cognitive load, which is necessitated by an application as a core usability attribute (Harrison et al. 2013).

The term evaluation is generally used to describe a structured and objective evaluation of an object of investigation. A usability problem can be defined as a problem that a user encounters when using the system to complete a task within an application scenario (Alshamari / Mayhew 2009). A usage problem is attributed to a usability defect arising due to a violation of a usability principle and can have negative consequences for the user (Marcilly et al. 2015). For the early detection of problems and thus, avoidance and limitation of the negative consequences, usability evaluation methods are used. The methods can be classified into qualitative methods producing data, which has to be interpreted (testing, observing, and questioning), and quantitative methods, which are based on defined metrics having numerical and objective data as a result (simulation and analytical modeling) (Ivory / Hearst 2001). For qualitative methods, moderated method types with little automation are common, such as observation and recording, interviews, think-aloud protocols, or heuristic methods. For quantitative methods in practice, unmoderated method types are frequently used, such as online questionnaires based on the usability scale system (Tullis / Albert 2013), the automated metric recording of an object of investigation, or a task model (Nielsen 1994).

The methods are used in various test environments, which is one influencing factor in the four-factor framework of contextual fidelity that describes the quality of the results of a usability evaluation (Sauer et al. 2019). Accordingly, the test environment has to resemble the actual operational environment in order to avoid a negative impact on quality. The laboratory test is one of the most frequently used test environments (Kolbe / Ruch 2014) since it takes place in a controlled and open definable context, almost free of accidental environmental influences. This allows collecting data through a variety of instruments during a moderated evaluation, which is highly specified and consequently exactly reproducible. Due to the versatile use cases of a smartwatch, the simulation of the particular environment in a laboratory test is a considerable challenge (Zhang / Adipat 2005). The research on automated usability measurement of smartwatches is still in its infancy. Recent methods split into static analysis, evaluating the source code and especially the design files during the development, and dynamic analysis considering user interactions. With reference to the previous remarks, the focus of this work are quantitative and automated usability evaluation methods.

Besides the theory about usability, there is related research, especially in the domain of mobile and web applications. Fourney et al. (2010) have expanded qualitative usability analysis by including the results of search engines or social media. Harrison et al. (2013) did an extensible literature review on the usability of mobile applications and demanded a new usability model. Balagtas-Fernandez / Hussmann (2009) propose a methodology and a framework to aid developers during the preparation of mobile systems for usability analysis. Ahmad et al. (2014) evaluated the usability of smartphones with a usability testing approach considering *Android* and *iOS*. Lettner / Holzmann (2012) developed an automated and unsupervised system for usability evaluation by user interaction logging. Furthermore, there are the *HUI Analyzer* of Baker et al. (2008), the *EvaHelper* framework (Balagtas-Fernandez / Hussmann 2009), and the *toolkit for usability testing* of Ma et al. (2013). A number of studies cover logging on websites like Grigera et al. (2017), who used usability smells to automatically generate a usability report. Beyond the scientific work, there are several commercial products, such as *Google Analytics*, *Flurry Analytics*, *Localytics,* or *User Metrix*, which allow the user to log on native and web-based applications.

In the domain of smartwatches, initial efforts arose in the last couple of years. Chun et al. (2018) conducted a qualitative study to assess the usage and usability of smartwatches and elaborated guidelines for future smartwatches. Park et al. (2018) examined different types of menu interfaces for smartwatch applications in a qualitative study. Finally, Wong et al. (2017) considered the usability of smartwatches used for cheating in academic examinations.

6.3 Research Design

To target the research gap regarding the dynamic usability analysis of smartwatch applications, we applied a mixed-methods approach based on the problem-centered design science research process model by Peffers et al. (2007), as shown in Figure 51.

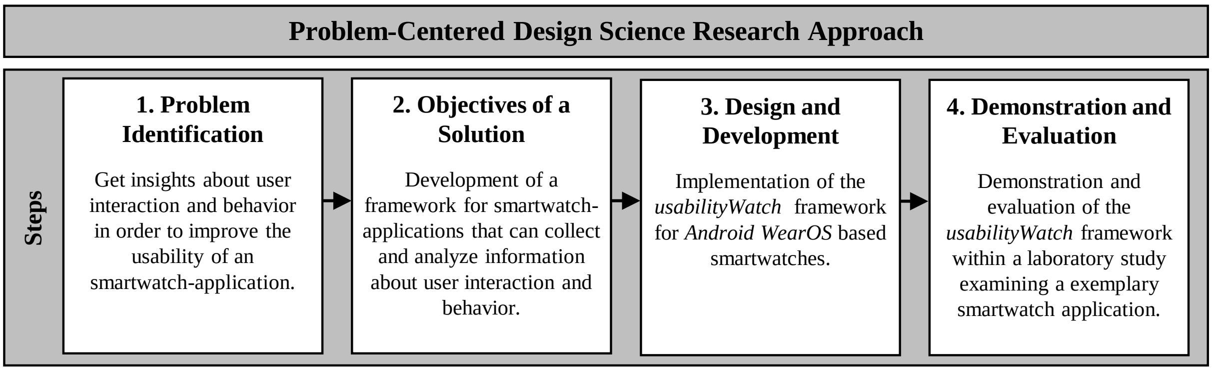


Figure 51. Research design

According to the process model, the development of the usability framework should be grounded in the problem identification phase (step 1). To this aim, we rely on a structured literature review following vom Brocke et al. (2009). The main goal of this literature review is to gain a holistic view of recent approaches to usability analysis on mobile devices. This builds the foundation for an investigation of eligibility and possible adaption in order to apply these methods on smartwatch applications considering the device-specific characteristics. With these characteristics, we can infer objectives and requirements for the framework design and development (step 2). Following the design science research process model, we implemented a prototypical framework called *usabilityWatch* based on the requirements (step 3). Subsequently, we did a demonstration and evaluation, according to Peffers et al. in step 4. For this, we integrated the *usabilityWatch* framework into an exemplary smartwatch application and conducted a laboratory study. We asked the participants to perform a task within a given scenario using a smartwatch application that supports employees in workflows. During the task, multiple paths and UI-elements have to be used, and usability-events are logged by the framework. Finally, the gathered data can be analyzed to access usability-insights.

6.4 *usabilityWatch* Framework

In this section, we present the design of the usability framework *usabilityWatch*, which addresses the identified research gap. It simplifies the typical set of tasks for usability evaluation conducted by a developer, including the preparation of a targeted application and the test environment, the data collection, the extraction of information, and the data analysis (Balagtas-Fernandez / Hussmann 2009).

6.4.1 Problem Identification

Based on the structured literature review, we identified a lot of research regarding usability for mobile information systems (see section 6.2). But so far, there is little effort to analyze usability on smartwatches. Certainly, most qualitative methods, e.g., laboratory tests, can be applied to smartwatches as well. Since 60 % of software problems are associated with the graphical user interface, which though in 5 % lead to a system crash, but have a negative effect on usage in 65 % (Robinson / Brooks 2009), the users' behavior can reveal most of the usability defects. However, there are no approaches to automatically and dynamically assess usability by analyzing the users' interaction with the application, considering the special characteristics of smartwatches.

6.4.2 Objectives of a Solution

In order to address the first research question (RQ 1), the existing literature is analyzed for requirements for the automated measurement of usability on mobile devices. From more than 40 occurring requirements, we elaborated seven requirements for our usability framework by selection and adoption in regard to smartwatches. We structured these into the domains of data collection and data analysis (see Table 32).

Data collection		Data analysis	
R_1	automated recording of user inputs and interactions	**R_5**	flexible data segmentation and visualization on a decent screen size
R_2	tester-oriented usability metrics handling the broad range of hardware and display resolutions of smartwatches	**R_6**	evaluation methods for a large amount of data with decent processing capabilities
R_3	simple integration in existing smartwatch applications to collect data within real application environments	**R_7**	usability-defect analysis
R_4	solid data transfer in spite of limited connectivity and power		

Table 32. Requirements for data collection and analysis

Our aim is to implement a framework that provides a dynamic usability analysis. Although in *Wear OS* development structured layout files (XML) exist, which can be analyzed statically beforehand, we focus on the direct user interaction due to the highly restricted range of input elements on smartwatches. The static analysis does not offer a substitute for insights from the actual use of an application by the user captured by defined metrics (Baker et al. 2008) and depends strongly on the target device size and form factor. In order to determine the actual use of an application in the context of dynamic analysis, the recording of user interactions is a core functionality (R_1) (Wetzlinger et al. 2014). The degree of automation should, as far as possible and reasonable, be considered (Baker et al. 2008), and the evaluation should be transparent for the user and has not to interfere with or disturb normal use (Muhi et al. 2013). For the data collection, the framework has to provide appropriate metrics (R_2) that can provide measurements, e.g., a swipe-to-touch ratio or dwell times, based on the recorded data. They have to be selected for the special characteristics of smartwatches as small display sizes and a broad range of hardware. The metrics should be tailored for the interest groups of the evaluation results in order to provide them with easy access to the necessary information. Overall, the framework should be designed for simple integration in existing smartwatch applications without a high programming effort (R_3). Since laboratory environments compromise the detection of usability defects due to an unrealistic situation, the framework should be robust, inconspicuous and therefore usable in real application environments (Muhi et al. 2013). Due to the high level of miniaturization, the limited computing and battery capacity get into the focus (Lee et al. 2017). In addition, the connectivity of a smartwatch to wide area networks cannot be assured at any point in time. Furthermore, the available transfer volume of data is only seldom unlimited and should, therefore, be taken into account. Thus, the framework has to provide solid data transfer (R_4). The purpose of data analysis is to draw conclusions. For that, in the first step, data segmentation is required (R_5), facilitating to view and compare the data in different dimensions

(Heo et al. 2009). In order to meet the changing demands of evaluation, flexible and modular architecture is necessary (Muhi et al. 2013). Furthermore, it should be possible to process and analyze the collected data using appropriate methods (R_6) (Wetzlinger et al. 2014). Since data collection can get extensive over time and scales with the number of users, computationally involving operations have to be handled in a way that does not exhaust the hardware capacities of smartwatches. Finally, usability defects should be derived from the prepared data (R_7), which makes it possible to improve a smartwatch application due to these insights (Heo et al. 2009).

6.4.3 Design and Development

To meet the elaborated objectives, we designed and developed the usability framework for smartwatch applications *usabilityWatch*. The overall architecture (illustrated in Figure 52) is split into a smartwatch component that is integrated into a targeted *Wear OS* (previously *Android Wear*) smartwatch application and a server component that gathers the arising data and provides usability reports to the developer. This architecture enables us to utilize the smartwatch for direct data collection, observing the behavior of the user, and overcome device limitations for a decent data analysis due to higher computing capacities provided by a server. In reference to R_5, data should be visualized on an appropriate screen size, which is not the case with a smartwatch. Furthermore, regarding R_6, it exceeds the computing power of a smartwatch to process large amounts of data. Anyway, a server is required to gather the data from multiple devices and users.

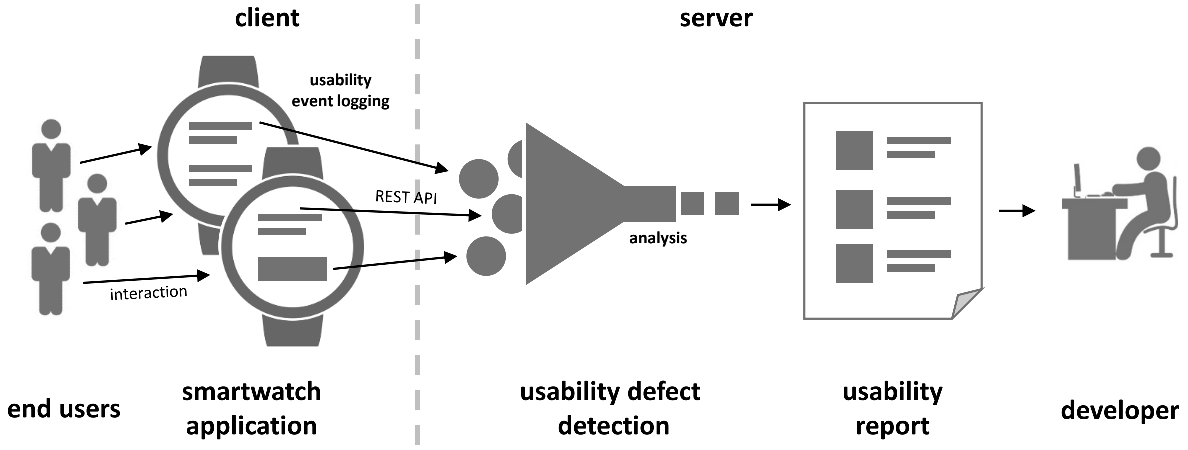


Figure 52. *usabilityWatch* architecture

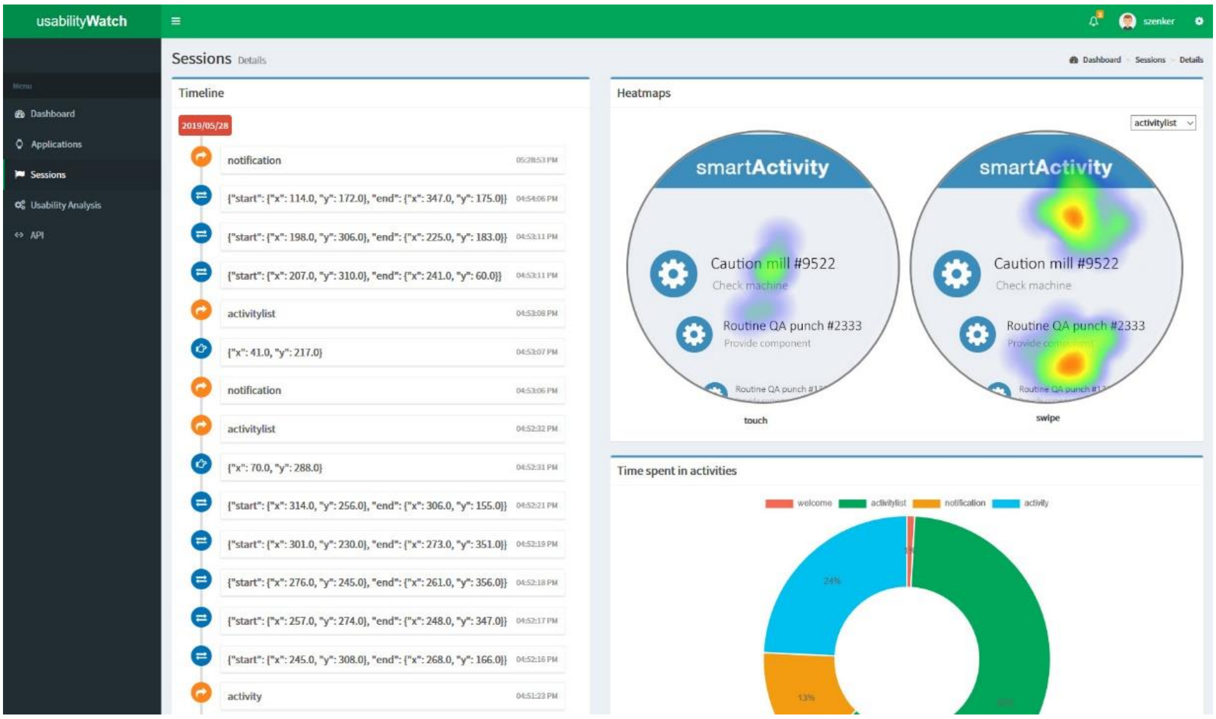
In the domain of the smartwatch application of interest, we provide a lightweight framework component, which in reference to R_3 can be easily integrated by including and compiling the framework’s Java package into the application’s main activity. It seamlessly hooks into the required event handlers, overloads non-invasively application methods, and implements the usability event logging as well as the communication to the server component. To access the full potential of the framework, the integration can benefit from aspect-oriented programming, e.g., *AspectJ,* which increases modularity, full separation of the frameworks and the application code, and weaves the framework functions into the desired event listeners during the build process (Enriquez / Casas 2017). Besides the wireless connection to the server, the framework does not require more effort to implement, and it is completely invisible to the user and does not interfere with the normal usage since it runs in the background within a separate thread. As nowadays, wireless network access is ubiquitous and already constitutes a prerequisite for many smartwatch applications, the framework can be applied in a broad range of environments.

In order to capture significant usability events from the interaction of a user with the smartwatch application to be examined and to meet R_1, *usabilityWatch* automatically logs the major issues occurring on a smartwatch. This includes (1) touch events (cf. clicks), (2) swipes (cf. scrolling), and (3) navigation events (changing the context of the screen). Since other components are mostly used to call operating system functions or other applications, e.g., a voice assistant, which interrupts the use of the targeted application, we neither consider interactions using hardware buttons due to the large heterogeneity of hardware devices providing a broad range of different numbers of buttons equipped with different functions nor touch gestures which are differently assigned for every underlying operating system. We consider R_2 by capturing metadata for all usability events outlined above. These are timestamps for all events, the coordinates for touch events, the start and end coordinates for swipe events, and a screenshot after navigation events. This also contains information about the UI elements that were interacted with and information about the device as the screen size as well as the form factor. In the analysis phase, the data can be combined in different ways to obtain usability insights.

For smartwatches, persistent network access cannot be assumed due to possible poor wireless coverage or overload, and transmissions reduce the limited power of smartwatch devices. To address R_4, the framework first stores occurring usability events internally. Occasional, this buffer is automatically sent to the server. If an error occurs, this is repeated until a connection is available, and the server consequently returns successfully. For communication, we implemented a REST interface (Malik / Kim 2017), which is easy to use, fast, reliable, and incorporates security aspects by using HTTPS.

For the server component, we use the combination of PHP and a relational MySQL database to benefit from their abilities related to web applications. In this way, we provide a desktop backend that is empowered with modern web technologies like HTML5 and makes it easy for developers to configure and access the usability analysis. As presented in Figure 53, *usabilityWatch* provides five main sections that can be accessed over the menu. First, there is a *Dashboard* that gives an overview, including important key figures. Furthermore, it surveys how many users and sessions for each tracked application have already been recorded. Second, in the *Application* section, smartwatch applications can be added, configured, and removed. Only data of registered applications are recorded; other requests are being rejected. In addition, the overall behavior of the REST interface can be configured in the API section.

In order to address R_5, we implemented the *Session* section (depicted in Figure 53), which provides data segmentation over sessions and different dimensions as well as various visualizations of the recorded data. On the left side panel, *usabilityWatch* provides a comprehensive timeline that visualizes all events of a selected session. User interactions like touch and swipe events are illustrated in blue, a particular icon, and show their coordinates of occurrence. Navigation events, which can be the result of a touch or are triggered by the smartwatch application, are illustrated in orange and respectively show the name of the reached screen. In addition, the navigation paths can be investigated with a Sankey diagram. The upper right side panel shows heat maps that aggregate all touch (left) and swipe (right) events, which can be segmented by the corresponding screen name. Areas of the screen, which show a high number of interactions, are dyed red; areas with low interaction are dyed blue. Since *usabilityWatch* captures screenshots, these heat maps can overlay the visible contents to facilitate the interpretation of this visualization. On the lower right panel, the relative distribution of dwell times is shown in a doughnut chart. It illustrates how much time a user stayed on a certain screen, which is the time difference between two subsequent navigation events.



```
2019/05/28
notification 05:28:53 PM
{"start": {"x": 114.0, "y": 172.0}, "end": {"x": 347.0, "y": 175.0}} 04:54:06 PM
{"start": {"x": 198.0, "y": 306.0}, "end": {"x": 225.0, "y": 183.0}} 04:53:11 PM
{"start": {"x": 207.0, "y": 310.0}, "end": {"x": 241.0, "y": 60.0}} 04:53:11 PM
activitylist 04:53:08 PM
{"x": 41.0, "y": 217.0} 04:53:07 PM
notification 04:53:06 PM
activitylist 04:52:32 PM
{"x": 70.0, "y": 288.0} 04:52:31 PM
{"start": {"x": 314.0, "y": 256.0}, "end": {"x": 306.0, "y": 155.0}} 04:52:21 PM
{"start": {"x": 301.0, "y": 230.0}, "end": {"x": 273.0, "y": 351.0}} 04:52:19 PM
{"start": {"x": 276.0, "y": 245.0}, "end": {"x": 261.0, "y": 356.0}} 04:52:18 PM
{"start": {"x": 257.0, "y": 274.0}, "end": {"x": 248.0, "y": 347.0}} 04:52:17 PM
{"start": {"x": 245.0, "y": 308.0}, "end": {"x": 268.0, "y": 166.0}} 04:52:16 PM
activity 04:51:23 PM
```

Figure 53. *usabilityWatch* session analysis

Finally, R_7 is implemented in the Usability Analysis section. Here the data is analyzed with a holistic view in order to generate insights into usability-defects. We elaborated and implemented several usability smells made for the specific needs of smartwatch applications. These can identify evidence for usability-defects, which are attributed to a violation of a usability-guideline leading to a problem for the user by a specific pattern of usability events in the collected data. Similar to Grigera et al. (2017), we list the usability smells, anomalies of events, and suggested refactoring that we derived from our previous studies in Table 33. To some extent, similar smells in different contexts were also identified in the literature (like *unresponsive element* and *distant content* in web-applications (Grigera et al. 2017)). The *unresponsive element* smell occurs whenever a user attempts to touch on an element that does not respond to touch events. This happens when elements look like buttons, but they are not. The smell can be detected by scanning for touch attempts that do not have a subsequent action. Similar to this smell *inappropriate swipe area* appears when the user attempts to scroll on elements with a swipe gesture, but the target is not able to scroll. This can happen if an element either does not support scrolling or the user started the swipe outside of the swipe area and can be identified by looking for swipe attempts without further action. Next, the framework provides the swipe-to-touch ratio metric. Looking at this value for each screen individually, the *incomprehensible list* smell can be detected if the value is unusually high. Ordinarily, a user scrolls through a list and touches the element of interest. In the optimal case, the mentioned ratio is 1 because it needs one single swipe to locate the desired item and one touch to activate it. A high ratio indicates that the user has to swipe a lot until the element is found. This happens for lists with many elements in an unfavorable order or a confusing list structure. The *missing confirmation* smell occurs when a touch to an element instantly leads to an influential action, e.g., a change of data or the application state. If this is unintended by the user, the restoring action can be found in the logs. Slightly different is the *missing feedback* smell. Here the user tends to check a change of data or an application state due to missing feedback subsequent to an action. Loops in the navigation path can reveal this in the data. Next, the *missing processing indicator* smell identifies computationally involving actions that block the UI for a time. For users, it is confusing if the application is not responding, and they start to touch somewhere. To avoid that, a processing indicator can clarify that actually an action is performed and the user has to wait. Finally, there is the *distant content* smell that occurs for unnecessarily complicated navigation. A user has to navigate through several screens until the targeted content is arrived. If repeating navigation patterns without any other interaction on the screens in between are detected in the data, a direct navigation element can facilitate the user to use the application more effectively. Ultimately, since the analysis of the huge amount of data is done on the server-side, R_6 is met as well.

Usability smell	Usability events	Refactoring
Unresponsive element	touch attempt on an element without any subsequent action	change UI appearance or add functionality to the element
Inappropriate swipe area	swipe attempt on an element without any subsequent reaction	change UI appearance, add UI interaction to the element, or increase and highlight swipe area
Incomprehensible list	high swipe-to-touch ratio on a list	increase size of list widget, revise sorting or reduce number of elements
Missing confirmation	repeating action while restoring the previous state	add confirmation prompt before action execution
Missing feedback	repeating loops in navigation path pattern	add visual feedback when the action was performed
Missing processing indicator	long request delays navigation after button touch	add processing indicator
Distant content	repeating navigation patterns without non-navigation touch and swipe interaction in between	add direct navigation element

Table 33. Usability smells with the associated usability events and recommended refactoring

6.4.4 Demonstration and Evaluation

For demonstration and evaluation, we conducted a laboratory study with 12 participants. We implemented the *usablilityWatch* framework in the exemplary smartwatch application *smartActivity,* which provides collaborative support for employees in industrial workflows (Zenker / Hobert 2019, study 1). For that, an employee can receive, process, and return activities according to a defined workflow. The application is composed of four screens: (1) a welcome page at the start of the application (*welcome*), (2) a list of assigned activities as illustrated in Figure 53 (*activitylist*), (3) a notification screen that informs a user about incoming activities that can be accepted or postponed (*notification*) and (4) a detail screen for a selected activity with a list of possible next steps according to the workflow as illustrated in Figure 55 (*activity*). During the study, the participants took the role of a technician who is responsible for several computer-operated milling and punching machines and traversed a scenario including various machine alerts and requests of a quality assurance department. After the scenario was completed, they were asked to fill in a predominantly qualitative questionnaire in order to evaluate the overall usability and usability problems that occurred during the operation of the smartwatch application. This enables us (1) to collect and analyze realistic data with *usabilityWatch* and (2) to have insights about the usability problems of real users. Matching both assessments allows us to evaluate the utility of the developed framework.

After conducting the laboratory study, we asked the participants to provide us feedback about usability. On the one side, the participants highlighted several positive aspects regarding usability, like the clear arrangement of the application, intuitive use, a low number of touches to process activities, and fast loading times. On the other side, several problems were stated. Concerning lists, the participants mentioned, *“the overview of activities automatically jumps up again very quickly, which makes the selection difficult”* (participants 5 and 6, 8, 9, 10) and *“the selection of the possible next work steps on the detail screen is very small”* (participants 5 and 2). Both comments reveal serious problems since the list at the *activitylist* screen jumps to the top every five seconds whenever the list is updated due to a messy implementation, which disturbs the selection of the desired element and requires another swipe. *usabilityWatch* detects both problems utilizing the swipe-to-touch metric shown in Figure 54.

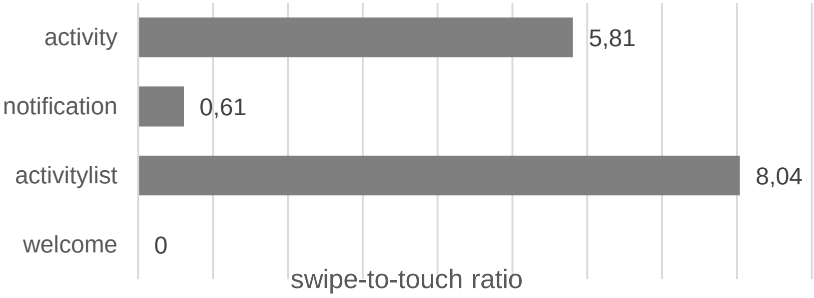


Figure 54. Swipe-to-touch ratio for the different screens

The swipe-to-touch ratio outlines a very high value for *activitylist,* indicating that for each selection, many swipes are required. The list at the *activity* screen also triggers a high value that is more related to the small size, which can be proved by the high number of unsuccessful swipes in the vicinity of the list. The *incomprehensible list* and *inappropriate swipe area* smells are reported accordingly since the optimal sequence is to swipe to the element and touch it, resulting in a value of 1. Another issue is described as *“the back button was only half displayed and therefore hard to reach”* (participants 4 and 5, 6, 7, 8). This can easily be seen in Figure 55 and is caused by an unintended shift of the whole layout of *smartActivity* to the bottom (small white area at the top). *usabilityWatch* reports the *unresponsive element* smell for touches close to the button. In combination with the heat map given in Figure 55, this issue can be detected.

Figure 55. Touch heat map of the activity screen

As the last commonly listed usability problem, we got "*faulty touches quickly lead to unwanted entries*" (participants 4 and 2) and "*I like to have more feedback that an action was executed after I touched a button*" (participants 3 and 8). So far, there is neither clear feedback that an action succeeded nor a confirmation prompt if an action should be performed. This leads to user behavior in which the action is checked or restored subsequently. The framework reports the missing feedback and missing confirmation smell due to a looping index of 3.2 and 2.7, respectively.

Summarizing, *usabilityWatch* can identify the reported usability problems within the recorded data. Some of the defects can be found completely automatically. For others, the usability smells are just an indication and have to be combined with other (visual) metrics to conclude the defect.

6.5 Discussion and Conclusion

In this paper, we presented a usability framework for smartwatches. Inspired by the design science research method (Peffers et al. 2007), we illustrated a problem-orientated research design. We first identified and described usability methods that are recently used for mobile devices (RQ1) since the usability analysis of smartwatches is a research gap. We formulated objectives and inferred requirements based on the conducted structured literature review and considered the unique characteristics of smartwatches. We presented the *usabilityWatch* framework composed of a smartwatch component and web backend (RQ2). It provides easy integration into a smartwatch *Wear OS* application, automated logging of user interactions, visualization of the collected data with, e.g., heat maps, and the analysis of usability defects. For that, we elaborated a list of usability smells suited for smartwatches. Finally, we proved in a demonstration and evaluation that the framework could find similar usability defects as the participants of a laboratory study for an exemplary smartwatch application.

There are some limitations to our research study. Since usability is a well-researched topic, the related literature is extensible, and we cannot claim our review to be complete. Second, we tested the framework with just one exemplary smartwatch application within an exemplary scenario. We are planning to do tests with more applications in order to improve the modularity and simplicity of integration of the framework. Furthermore, we want to extend the list of usability smells and like to optimize the thresholds for the existing smell metrics towards realistic values by expanding the practice. Though, the application of the framework requires a proper interpretation of the results in order to benefit from the generated insights and to identify false positives that may occur in the automated analysis. In addition, the user of the framework has to be aware of metrics like the swipe-to-touch ratio, which can be misleading whenever multiple scrollable elements appear on the same screen (unlikely due to small screen size), or the screen itself can be scrolled. Since hardware buttons or digital crowns are noted as very pleasant, these should also be included in the corresponding scrolling metrics, which remains a complicated problem due to heterogeneous hardware and software widgets.

Nevertheless, we verified the utility of *usabilityWatch* in a realistic scenario and contributed to practice and research. The developer of smartwatch applications can benefit from usability insights in order to reduce a user’s cognitive load and to improve their applications. This can easily be done by analyzing the user’s interactions, and no time-consuming and expensive qualitative studies like laboratory tests are required. For practice, we created an applicable software solution for targeting automatic usability analysis on smartwatch devices in order to support developers. Within the research domain, we reviewed recent approaches and methods, modified and complemented them according to the unique characteristics of smartwatches covering main aspects of the PACMAD model. This transfer of methods forms the foundation for future studies for usability analysis on smartwatches.

C Contributions

The presented studies aim at investigating the utilization of smartwatch-based information systems in the corporate context. This extensive objective has been subdivided into the three research complexes (I) smartwatch-based information systems supporting mobile employees executing manual work, (II) smartwatch-based information systems at the office workplace, and (III) usability of smartwatch-based information systems. This scope provides a multi-faceted and holistic view on the design principles of mobile information systems in the digital transformation of the workplace and, in particular, the utilization of smartwatch-based information systems in the corporate context.

As illustrated in Figure 56, in section C.1, the contributions of the individual research articles founding this cumulative thesis are briefly reiterated and related to the overarching meta-research questions formulated in section A.2. Subsequently, in section C.2, the practical and theoretical implications of these findings are discussed, and the contributions for research and practice are outlined. Finally, the methodical and contextual limitations are emphasized in section C.3 to motivate future research avenues based on the presented thesis in section C.4.

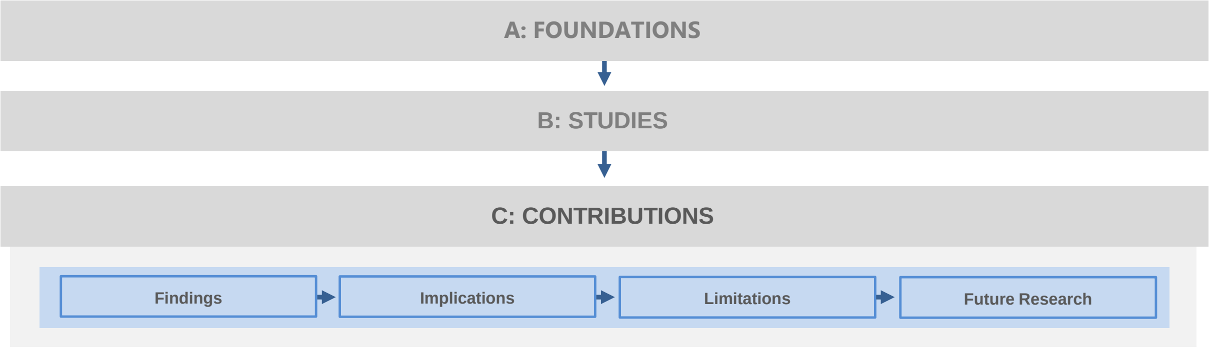


Figure 56. Structure of thesis’ part C presenting the research contributions

1 Summary of Results

This section surveys the findings regarding the meta-research questions outlined in section A.2. For that, the meta-research questions are reiterated, and the contributions are summarized. As illustrated in Figure 50, these results were developed based on six studies presented in part B of this cumulative thesis. The studies refine and address the three meta-research questions described and outlined in section A.2. They are arranged in the three overlying research complexes. Hence, the research complexes constitute and cover the overarching domain of this thesis about the utilization of smartwatch-based information systems in the corporate context from a design perspective.

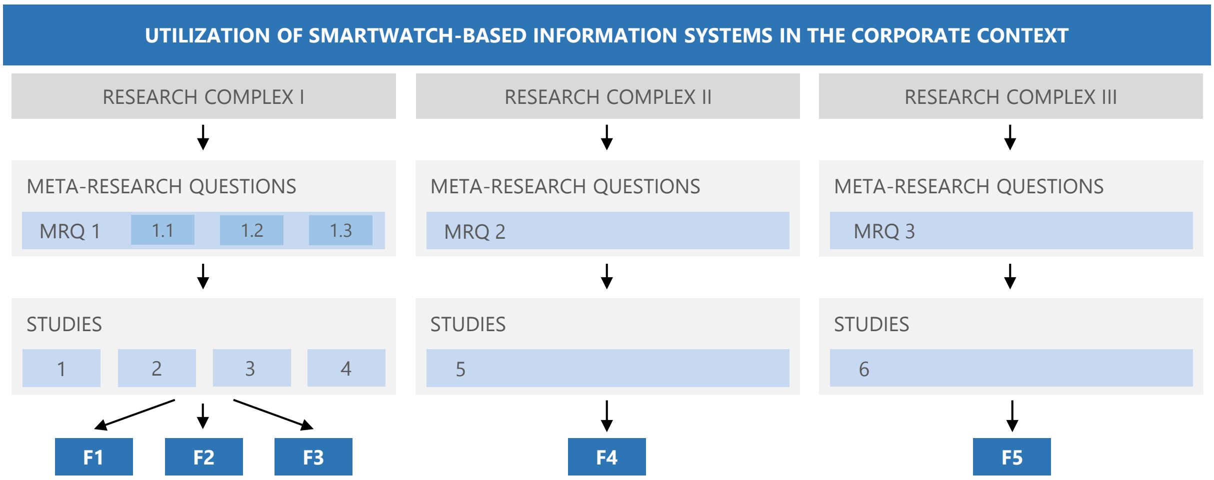


Figure 57. Research progress from objective to findings

The central findings (F) of this theses are:

> **F1:** The utilization of smartwatch-based IS can facilitate mobile employees executing manual work with an incidental and hands-free exchange of information, collaboration, workflow guidance, and context-awareness, decreasing the cognitive load and increasing the efficiency of work (Zenker / Hobert 2019, study 1; Zenker et al. 2020b, study 2; Zenker 2020, study 3; Zenker et al. 2020a, study 4).

> **F2:** According to the unique characteristics of smartwatches, smartwatch-based IS should comply with the design principles formulated in the nascent design theory for successful utilization in the corporate context to fully profit from the potentials and overcome the device-related limitations (Zenker et al. 2020a, study 4).

F3: Before utilizing smartwatch-based IS, technical, organizational, individual, and environmental prerequisites have to be considered formulated in the *Smartwatch Applicability Framework* (Zenker et al. 2020b, study 2).

F4: Smartwatches can be utilized for stationary work due they are directly connected to the employees' body and thus can demand the employees' attention as well as obtain sensor information, for example, for haptic notification of messages through vibrations or corporate health promotion programs (Wesseloh et al. 2020b, study 5).

F5: The usability is a crucial success factor of smartwatch-applications and can automatically be analyzed for improvement with the developed *usabilityWatch* framework (Zenker / Hobert 2020, study 6).

The meta-research questions for each of the research complexes covering the different aspects of this cumulative thesis can hence be answered as follows.

1.1 Research Complex I

RESEARCH COMPLEX I:
SMARTWATCH-BASED IS SUPPORTING MOBILE EMPLOYEES EXECUTING MANUAL WORK

MRQ 1: How to design smartwatch-based information systems to support mobile employees executing manual work?

- **MRQ 1.1:** How to design smartwatch-based information systems for typical corporate scenarios?
- **MRQ 1.2:** What enabling and inhibiting factors for the adoption of smartwatch-based information systems exist?
- **MRQ 1.3:** How to generalize and assemble the gathered knowledge?

Research complex I targeting smartwatch-based information systems supporting mobile employees executing manual work is addressed by meta-research question 1. Since based on the unique characteristics of a smartwatch, this is the consequent field of application providing the most potential and thus is a complex and considerable domain constituting the principal part of this thesis, MRQ 1 is subdivided. First, MRQ 1.1 focuses on the design of smartwatch-based information systems in typical corporate scenarios. As illustrated in Figure 11, four use cases identified in empirical studies were investigated, and software solutions are designed. For MRQ 1.2, enabling and inhibiting factors of the adoption of smartwatch-based information systems in the corporate context were elaborated. Finally, in MRQ 1.3, the gathered design knowledge was generalized and documented in a nascent design theory.

According to Hevner (2007), the contributions of the overall design science research progress within research complex I addressing the smartwatch-based support of mobile and manual work is illustrated in Figure 58. This includes the environment, design science research, and the knowledge base interconnected by the relevance cycle, the design cycle, and the rigor cycle.

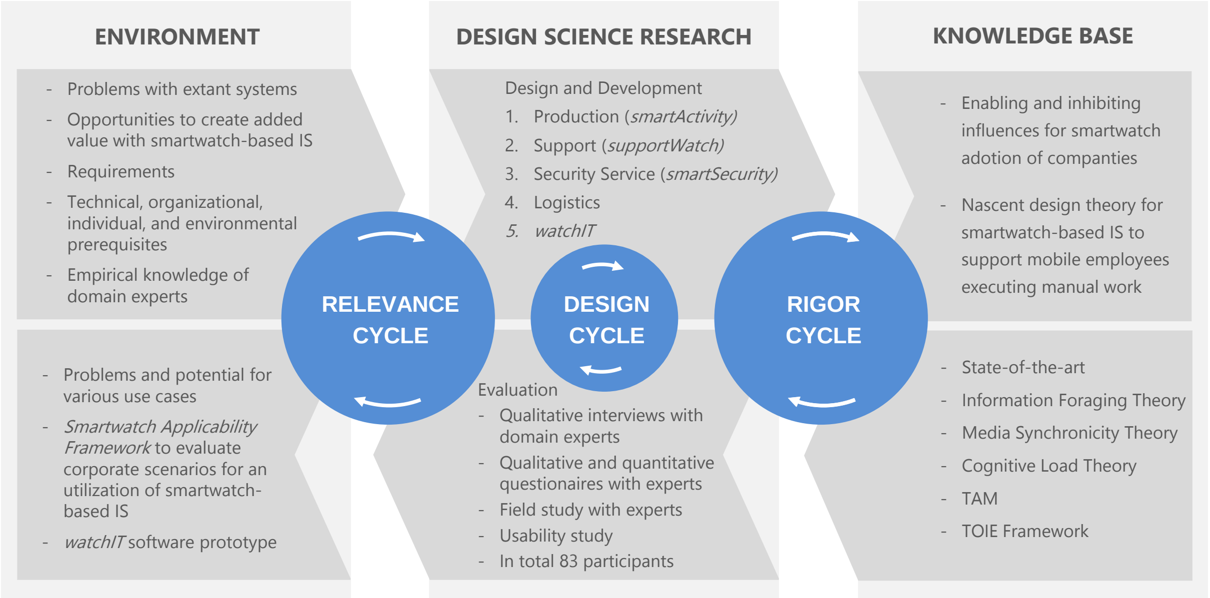


Figure 58. Design science research cycles with the respective contributions

The design science research approach conducted in the presented studies (center) was built on influencing factors of the environment (upper left) and the knowledgebase (lower right). During a workshop-series within an industrial production facility by Hobert / Schumann (2018) and the qualitative empirical studies by Zenker / Hobert (2019, study 1), Zenker et al. (2020b, study 2), Zenker (2020, study 3), and Zenker et al. (2020a, study 4) problems with extant systems and opportunities to create added value with smartwatch-based information systems in the corporate context have been identified. With focus interviews, including respective domain experts, requirements have been established. Furthermore, technical, organizational, individual, and environmental prerequisites are identified that enable and inhibit the adoption of smartwatch-based information systems by companies. As these statements emerged in practice and are formulated by domain experts of the various use cases, a high practical relevance represented by the empirical knowledge of domain experts can be confirmed. Thus, these factors are transferred to the design science research over the relevance cycle. From the opposite orientation, the knowledge base enriches the design science research progress with theoretical aspects. In particular, a structured literature review according to vom Brocke et al. (2015), vom Brocke et al. (2009), Fettke (2006), and Webster / Watson (2002) identified the state-of-the-art and exposed vast research gaps. Besides, the problem analysis is grounded with the Information Foraging Theory (Pirolli / Card 1999), the Media Synchronicity Theory (Dennis et al. 2008), and Cognitive Load Theory (Sweller 2011) that could be applied to the introduced scenarios. For the empirical studies and, in particular, the interview and questionnaire design, the Technology Acceptance Model (Davis 1989) and Technology-Organization-Individual-Environment Framework (Rosli et al. 2012; Hoong / Marthandan 2014) based on the Technology-Organization-Environment Framework (DePietro et al. 1990) are considered. Thus, this knowledge is transferred to the design science research over the rigor cycle, which consolidates the research in terms of scientific rigor.

The design science research process depicted in the center of Figure 58 is composed of five design cycles. This includes the coverage of four representative use cases identified in the empirical studies: (1) production, (2) support, (3) security service, and (4) logistics addressing MRQ 1.1 (F1). Since no additional use cases that exhibit substantial different characteristics rise from the last design cycles, all smartwatch characteristics are covered, and the requirements are predominantly confirmed than extended, a saturation of new design knowledge is reached. This design knowledge was generated during the design and development of the software-artifacts *smartActivity* (Zenker / Hobert 2019, study 1), *supportWatch* (Zenker et al. 2020b, study 2), *smartSecurity* (Zenker 2020, study 3), and an evaluation study withing a logistics scenario (Zenker et al. 2020a, study 4) following a design science research model inspired by Peffers et al. (2007). In a concluding fifth design science research cycle, the design knowledge is generalized and documented in a nascent design theory (F2) according to Gregor / Jones (2007), supplemented by the software meta-artifact *watchIT* (Zenker et al. 2020a, study 4). For the evaluation, the developed software artifacts are demonstrated in practice and assessed by domain experts during qualitative interviews, qualitative and quantitative questionnaires, and a field study as well as usability study. In total, 83 domain experts from a broad range of companies, departments, and backgrounds participated in the studies.

The design science research results in the form of gathered design knowledge finally circulate back to its origins. On the one hand, the rigor cycle transfers theoretical knowledge back to the knowledgebase and contributes to the research domain (upper right). Extent theory, e.g., regarding mobile IS, is modified and extended with aspects of smartwatch-based information systems in the corporate context. First, enabling and inhibiting factors that influence the adoption of smartwatches by companies are formulated addressing MRQ 1.2 and leading to F3 (Zenker et al. 2020b, study 2). Second, a nascent design theory for smartwatch-based information systems to support mobile employees executing manual work is proposed addressing MRQ 1.3 and leading to F2 (Zenker et al. 2020a, study 4). The underlying design principles can be used and verified by researches with the help of the dedicated testable propositions. On the other hand, the design science research progress transfers practical knowledge to the environment through the relevance cycle. Based on the extensive evaluations, the problems with extant systems can be refined, and the potential for the utilization of smartwatch-based information systems can be demonstrated, addressing MRQ 1.1 and leading to F1. As a practice-oriented contribution, the *Smartwatch Applicability Framework* offers companies the comprehensible opportunity to evaluate their own processes and workflows and obtain advice for the utilization of smartwatch-based information systems in their context or better-suited solutions which should be considered addressing MRQ 1.2 and leading to F3 (Zenker et al. 2020b, study 2). Furthermore, there is the *watchIT* meta-prototype that provides software for a smartwatch application based on *Wear OS*, as well as a server component including a web-based backend designed for the use on various stationary and mobile devices such as desktop PCs or smartphones addressing MRQ 1.3 and leading to F2.

Overall, MRQ 1 concerning the design of smartwatch-based information systems to support mobile employees executing manual work was addressed exhaustively. Although exemplary use cases are analyzed and investigated, the underlying scenarios are typical for mobile employees executing manual work and can be adapted to plenty of use cases exhibiting the same characteristics.

1.2 Research Complex II

RESEARCH COMPLEX II:
SMARTWATCH-BASED IS AT THE OFFICE WORKPLACE

MRQ 2: How to utilize smartwatch-based information systems at the office workplace?

Research complex II complements the previous research complex I with the investigation of smartwatch-based information systems at the office workplace. The underlying meta-research question is addressed by analyzing the digital support of workplace health promotion with a smartwatch-based and gamified information system for employees at office workplaces (Wesseloh et al. 2020b, study 5). For that, the software prototype *healthWatch* was designed, implemented, and evaluated, applying a research design inspired by the design science research methodology of Peffers et al. (2007). First, the corporate health scenario found in practice, including employees at office workplaces, a corporate health manager, and a technical administrator, was described. Based on a literature review, objectives, and inferred requirements for a subsequent development process have been formulated. A smartwatch application based on *Wear OS*, a web-based backend, and a server architecture building the *healthWatch* information system was designed and implemented. Finally, the software was evaluated and validated its utility according to 29 employees working at different office workplaces. Overall, smartwatches' unique characteristics can facilitate digital systems that support corporate health management as an example of the support of employees at the office workplace (F4).

The evaluation results revealed a mixed perception of the application's potential users. On the one hand, the employees recognized the various advantages of a digital solution based on a smartwatch. On the other hand, they also express their concerns about data privacy and surveillance by the employer. Nevertheless, most respondents still regard the system to be widely useful. To counteract privacy and surveillance concerns, the study emphasized to involve the employees, the company medical officer, and the workers' council in the early stages of the integration process to negotiate appropriate and transparent agreements (confirming F3).

Overall, an applicable software solution for the digital support of corporate health promotion was created. The popular idea of utilizing health values recorded by wearable devices, such as fitness trackers and native smartwatch functions, for health promotion in the private domain was transferred to the corporate sector. Also, this provides individual assistance for the employees, valuable feedback for a corporate health manager, and an approach to improve the quality of work at office workplaces. However, it does not deviate employees from work and can be used incidentally due to smartwatches' unique characteristics. During the design progress, insights about how to utilize smartwatches at the office workplace in the form of a novel information system have been gathered, and a conceptual approach including design guidelines has been contributed (F4).

1.3 Research Complex III

RESEARCH COMPLEX III:
USABILITY OF SMARTWATCH-BASED INFORMATION SYSTEMS

MRQ 3: How to analyze the usability of smartwatch applications?

As an auxiliary tool utilized during the development process of smartwatch-based information systems, research complex III targets the usability of smartwatch-based information systems. To address MRQ 3 and constituting F5, a usability framework for smartwatches was designed, developed, and evaluated (Zenker / Hobert 2020, study 6). During a problem-orientated research design inspired by Peffers et al. (2007), usability methods recently used for mobile devices have been identified and described since the usability analysis of smartwatch applications was a research gap. For that, objectives have been formulated, and requirements based on the conducted structured literature review have been deferred while considering smartwatches' unique characteristics. The presented *usabilityWatch* framework comprises a smartwatch component for data recording and a web backend for the analysis. It provides easy integration into a smartwatch *Wear OS* application, automated logging of user interactions, visualization of the collected data with, e.g., heat maps, and the analysis of usability defects. For that, a list of usability smells suited for smartwatches similar to Grigera et al. (2017) and Harms / Grabowski (2014) within the web domain was elaborated during a usability study, including a laboratory experiment with the *smartActivity* smartwatch application (Zenker / Hobert 2019, study 1). Finally, in a demonstration and evaluation, it has been proven that the framework can find similar usability defects as the participants of a laboratory study for an exemplary smartwatch application.

Overall the utility of *usabilityWatch* was verified in a realistic scenario, and the effort contributes to practice and research. Developers of smartwatch applications can benefit from usability insights to reduce a user’s cognitive load and improve their applications. This can easily be done by analyzing the user’s interactions rather than time-consuming and expensive qualitative studies like laboratory tests. An applicable software solution targeting automatical usability analysis on smartwatch devices to support developers was created for practice. Within the research domain, recent approaches and methods have been reviewed, modified, and complemented according to the unique characteristics of smartwatches covering central aspects of the PACMAD model (Harrison et al. 2013). This transfer of methods forms the foundation for refined usability analysis on smartwatches.

2 Implications

The research results obtained in this thesis can be further used in scientific research as well as in operational practice.

From the **scientific perspective**, the state-of-the-art of the utilization of smartwatch-based information systems was identified and systemized. It was shown that there are already some approaches and prototypes for the application of smartwatches in companies, but that there is little understanding of necessary requirements, design principles, and transferable concepts. In combination with the uncovered research gaps, the empirical findings highlight the existence of further research opportunities in many areas of application. The requirements and associated design principles derived from qualitative studies with domain experts and based on scientific theories were evaluated in qualitative and quantitative studies. They reveal the necessary functionalities and effects in the investigated application areas and confirm the suitability of smartwatches in the business context. Based on the TOEI framework (Rosli et al. 2012; Hoong / Marthandan 2014), enabling and inhibiting influences of the smartwatch adoption by companies have been developed (Zenker et al. 2020b, study 2). Together with the developed concepts, design principles, and prototypical implementations, the nascent design theory according to Gregor / Jones (2007) for smartwatch-based IS to support mobile employees executing manual work (Zenker et al. 2020a, study 4) represents a scientific design science research contribution of level two targeting level three according to Gregor / Hevner (2013). Thus, existing theories were modified and extended by smartwatch related aspects during the design-oriented approach. For example, this thesis's results comply with the ten lessons learned about enterprise wearable computer developed by Hobert / Schumann (2018), but in detail consider the unique characteristics of smartwatches and extend the design knowledge in the domain of smartwatches. Besides, with research complex III, existing usability analysis methods are identified, modified, and extended to be suited for smartwatch applications (Zenker / Hobert 2020, study 6).

From the **practice perspective**, this design-oriented cumulative dissertation offers a broad range of implications. These are illustrated in Figure 59, merging all contributions of this thesis in a practice-targeted smartwatch-based information system development process model. It is inspired by the waterfall model by Royce (1970) due to its simple structure and clearly defined phases with predefined intermediate results. As a procedure model, it can provide clear guidelines and sufficient margins to integrate modern software development processes like an agile approach (Takeuchi / Nonaka 1986). In contrast to the original, this forked waterfall model subjoins a second path implementing organizational aspects that have to be considered and are equally important on the left side in addition to the refined software development phases on the right side. It consolidates the findings of this thesis and provides decision-makers of companies a practical guideline to introduce smartwatch-based information systems in their specific corporate context.

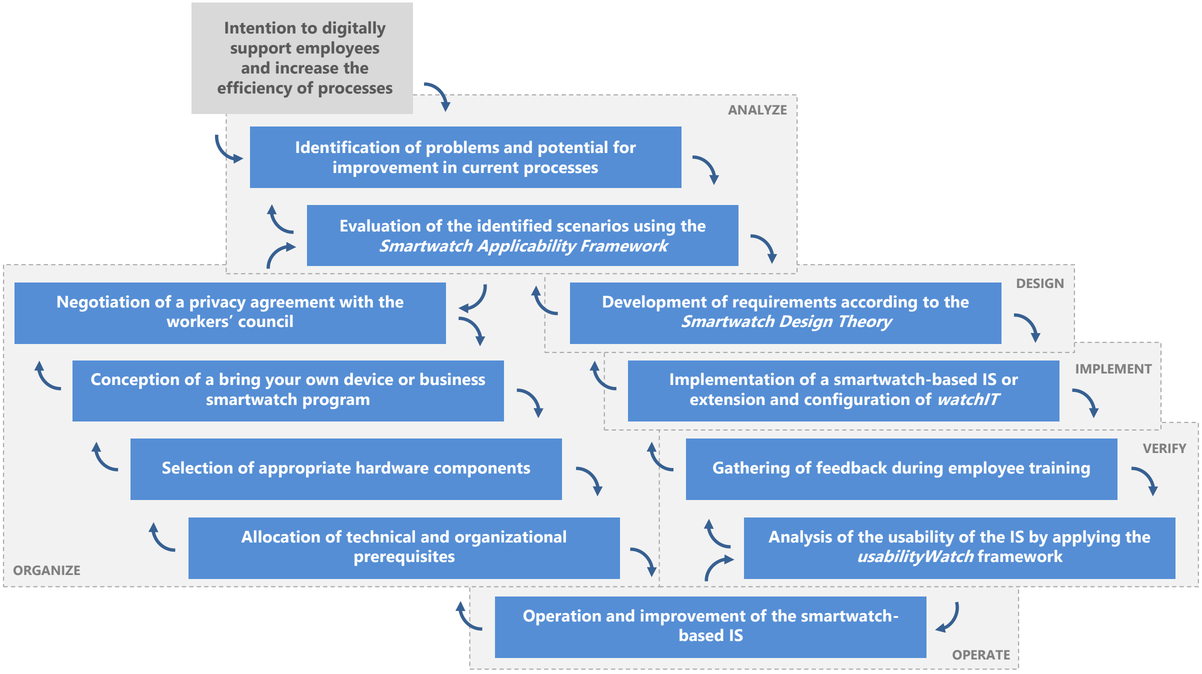


Figure 59. Forked waterfall model about the introduction of smartwatch-based IS

For the initial step, this thesis provides plenty of motivation emphasizing the potential of the utilization of smartwatch-based information systems in the corporate context. Once there is the intention of a decision-maker to digitally support employees and increase the efficiency of processes, as inspiration possible use cases for smartwatches that are both beneficial for companies and employees can be found in the conducted studies (Zenker / Hobert 2019, study 1; Zenker et al. 2020b, study 2; Zenker 2020, study 3; Zenker et al. 2020a, study 4; Wesseloh et al. 2020b, study 5). Companies have to identify problems and potentials for the utilization of smartwatches within their corporate processes and are guided with the *Smartwatch Applicability Framework* of Zenker et al. (2020b, study 2) during the analysis of scenarios. Here, the process splits into two paths that have to be traversed in parallel to reach a successful implementation of a smartwatch-based information system finally. The left side describes organizational and the right side technical aspects. Following the right side, first requirements have to be obtained that should consider the presented nascent design theory and could adapt the included design principles (Zenker et al. 2020a, study 4). These requirements are then implemented in a smartwatch-based system. For that, the *watchIT* artifact can be used as a foundation or can be modified, extended, and configured. During the verification phase, feedback from employee training should be gathered, and the usability of the smartwatch software should be analyzed by applying the *usabilityWatch* framework (Zenker / Hobert 2020, study 6). After this step, the technical aspects of the smartwatch-based information system development are concluded, and the system can be used in the operational phase.

Nevertheless, the steps of the organizational part are required to establish a successful integration of smartwatch-based information systems in the corporate context. As early as scenarios are identified for utilizing the smartwatches, a privacy agreement with the workers' council should be negotiated. This may take time and effort and influences the functionalities that can be implemented. However, otherwise, the project can rapidly fail due to insufficient consultation of the workers' council and lack of acceptance due to privacy concerns of the workforce since perceived privacy risk has a direct negative influence on the behavioral intention to use smartwatches (Ernst / Ernst 2016). Second, the employees' involvement can be strengthened with a business smartwatch or a bring your own device program where the employees have an influential voice. Nevertheless, such programs may increase the security risk because devices with potentially sensitive company data regularly leave the worksite (Siboni et al. 2018a). For that, policies have to be prepared like the encryption of data or access protection with PINs (Shen et al. 2020; Ferrari et al. 2015; Guerar et al. 2019). Besides personal preferences, e.g., according to the wristband material, appropriate hardware has to be selected in the next step aligning with the procedure model for the selection of wearable computers in the industry sector by Hobert (2018). Beyond the consumer smartwatches, there are special rugged devices for industrial use (WORKERBASE GmbH 2020). These smartwatches have to meet the specific characteristics and should comply with the expectations of the employees, e.g., larger screen sizes for older employees (Lutze 2018; Lazaro et al. 2020). Furthermore, technical and organizational prerequisites have to be ensured. This includes, for example, the coverage of the relevant work area with wireless access or the definition of workflows. Finally, if both waterfall paths are processed, successful long-term utilization of smartwatches in the corporate context is possible. During the operation of the smartwatch-based information system, continuous feedback should be gathered, new demands should be analyzed, and thus a constant improvement of the system can be achieved.

The thesis complements recent studies about wearable computer devices in the corporate context and illustrates the potential additional value of smartwatches supporting business processes (Mach et al. 2018; Legner et al. 2011). Regarding the Work Design Theory of Richard / Oldham (1976), smartwatches can help companies to provide motivating working conditions for their employees. Furthermore, smartwatch-based information systems can help to create common guidelines and to standardize processes. According to Sinha / van de Ven (2005), the complexity of work raise with an increasing number of hierarchical levels and organizational units, whereas smartwatch-based systems can be scaled and provide individual and context-related information to reduce the cognitive load of employees (Sweller 2011). Overall, the presented findings exhibit a high practice-relevance and guide companies discussing the utilization of smartwatches.

3 Limitations

This thesis contributes to the research domain of the design of mobile information systems and, in particular, to the utilization of smartwatches to support mobile employees executing manual work, employees at office workplaces, and the analysis of the usability of smartwatch applications. Nevertheless, there is a need for further research, which is mainly justified by the existing limitations of the conducted studies.

> **L1:** The preliminary literature review is limited to its scope.

Although the preliminary literature review is limited to its scope, the whole extent of smartwatch-related literature exhibiting corporate references was systematically reviewed, and the state-of-the-art was identified during the progress of the literature search. Eventually, the research of the utilization of smartwatch-based IS in the corporate context is in its infancy, and an increasing number of publications in recent years can be registered.

For **research complex I** and the underlying studies elaborating on smartwatch-based IS supporting mobile employees executing manual work (Zenker / Hobert 2019, study 1; Zenker et al. 2020b, study 2; Zenker 2020, study 3; Zenker et al. 2020a, study 4), the following methodical and contextual limitations exist.

> **L2:** The scope of the use cases production, support, security service, and logistics, and the range of the underlying scenarios are limited.

First, the extend of the presented use cases and their underlying scenarios is limited. According to Zenker / Hobert (2019, study 1), the production use case is based on a scenario composed of the interaction of machine operators within a shop floor and employees of the quality assurance department. The support use case presented by Zenker et al. (2020b, study 2) is based on three university scenarios: (1) student IT infrastructure support, (2) electronic assessment support, and (3) lecture hall technology support. According to Zenker (2020, study 3), in the security use case, the collaboration of security guards, security patrols, and the lone-working-protection are analyzed. The logistics use case considers storage, picking, and loading scenarios as they are identified as the most promising ones during a preliminary study with domain experts (Zenker et al. 2020a, study 4). Nevertheless, in each use case, representative scenarios are identified and analyzed.

> **L3:** The evaluation may be biased due to novelty effects, the participants of the studies could only test the application for a short time-frame, and only a few women participated.

Since the evaluation results are exceeding positive, novelty effects due to the high interest in smartwatches may bias the study. Furthermore, only a few female employees attended the evaluations. According to the experience from the studies, women have slightly different demands on mobile devices, especially when they are worn on the body. However, in physical occupations, the excerpt depicts a realistic scale for gender distribution since it is done by men predominantly. Furthermore, the evaluation participants could only test the application for a short time-frame during the demonstration phase.

> **L4:** The meta-software artifact and the nascent design theory are merely based on five design science research cycles, including four use cases.

The empirical foundation of the developed *watchIT* artifact and the design principles constituting the nascent design theory is predominantly based on evaluations from the previous use cases with a limited scope of companies. Nevertheless, the use cases emerged during empirical studies, and the design cycles reached a saturation where neither new use cases that exhibit substantial different characteristics appeared nor novel requirements are discovered.

Besides, there are techno-social limitations that are concomitant with smartwatches. As smartwatches are electronic devices, they cannot be used in environments where electronic radiation, electric discharge (e.g., the assembly of delicate electronic components), or sparks (e.g., in paint rooms with explosion hazard) can cause damage. Zenker et al. (2020b, study 2) showed that employees might have anxiety feelings while wearing a watch and, therefore, cannot benefit from such systems. Furthermore, the continuous presence of a digital device can foster technostress (Ayyagari et al. 2011; Dragano / Lunau 2020). According to Zenker et al. (2020b, study 2), the most critical factor for the acceptance of smartwatches as an innovative technology in the corporate context is privacy. Whenever employees have the feeling of surveillance and restriction of free will, such systems encounter rejection.

For **research complex II** and the underlying study about health promotion at office workplaces with a smartwatch-based information system (Wesseloh et al. 2020b, study 5), the following methodical and contextual limitations exist.

> **L5:** The requirements are merely based on literature and empiric knowledge from a university scenario.

During the design and development of *healthWatch* the requirements are merely obtained from literature and a university scenario. Nevertheless, literature provided plenty of approaches, and the university scenario includes a broad range of different office workplaces across the university’s departments.

> **L6:** The evaluation may be biased due to novelty effects, and the participants of the study could only test the application for a short time-frame.

Since the participants indicated that they had just a little experience with smartwatches, novelty effects may bias the evaluation due to initial high interest diminishing over time (Shin et al. 2019). Second, the evaluation is limited as the participants could only test the web-based component for a small time-frame during the online evaluation and got merely little information about the concept’s details. They were not able to test the whole system, including the smartwatch, at their workplace yet.

For **research complex III** and the underlying study about the design and implementation of a usability-framework for smartwatches (Zenker / Hobert 2020, study 6), the following methodical and contextual limitations exist.

> **L7:** The literature review has a specific and thus limited scope.

Since usability is a well-researched topic, the related literature is extensible, and the review cannot be claimed complete. In particular, Zenker / Hobert (2020, study 6) focused on the automatic and dynamic analysis of usability. For that, usability smells (Grigera et al. 2017; Harms / Grabowski 2014) are used to generate usability reports and gather usability insights.

> **L8:** The *usabilityWatch* framework and its underlying usability smells and metrics are based on one exemplary smartwatch application within an exemplary scenario.

The metrics and usability smells are developed based on the literature and a laboratory study, especially the study considered merely one smartwatch application examined by 12 participants within one traversed scenario. However, a neat extent of usability issues is covered due to the simplicity of smartwatch user interfaces in terms of the diversity of elements placed on the small display, diminishing the range of input options to be investigated, like the absence of text input (Chaparro et al. 2015).

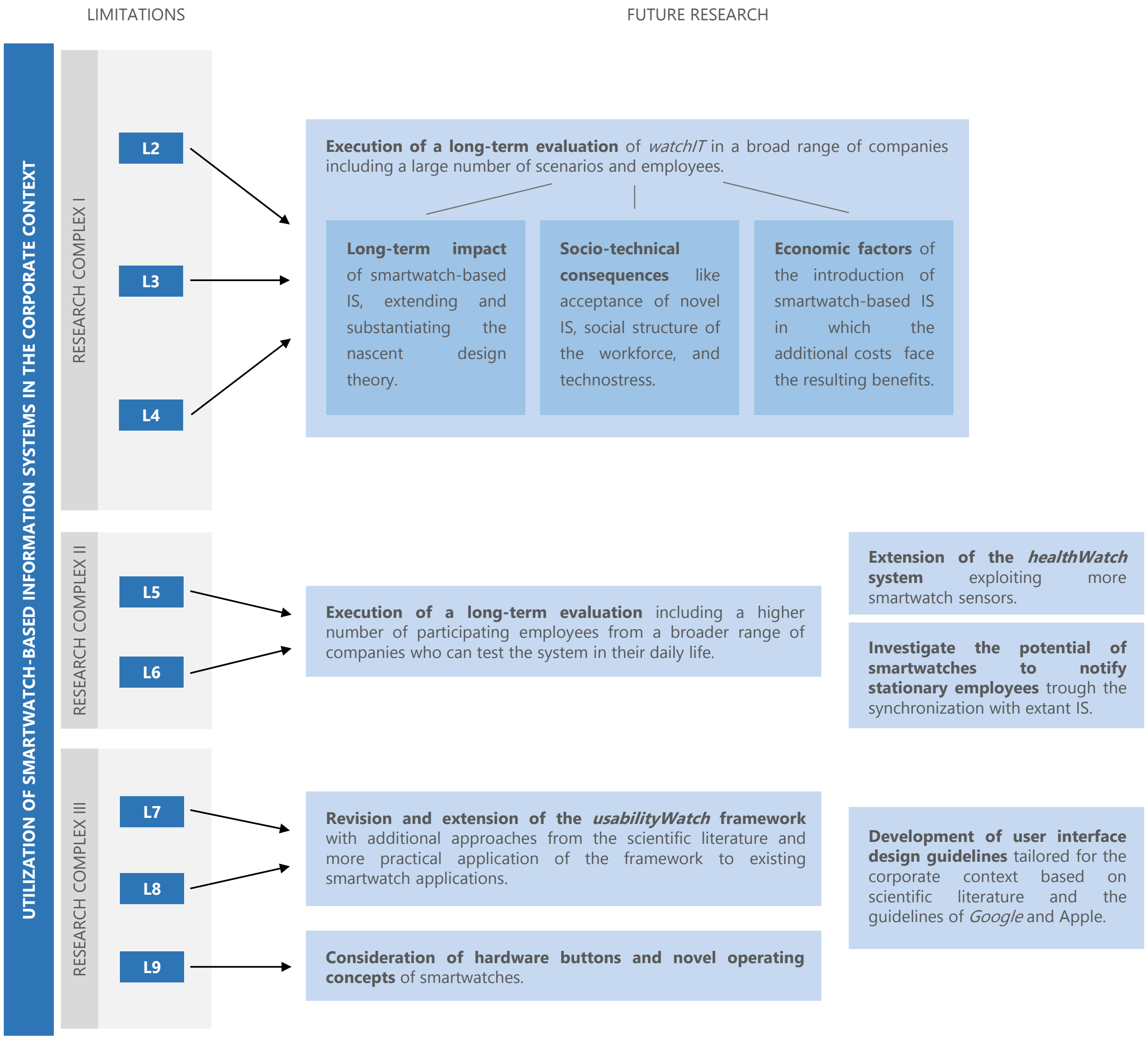
> **L9:** Beyond the touchscreen interactions, hardware buttons, or digital crowns are not considered yet.

Since hardware buttons or digital crowns are noted as very pleasant (Brulé et al. 2018), these should also be included in the corresponding scrolling metrics, which remains a complicated problem due to heterogeneous hardware and software widgets.

Overall, the number of participating domain experts and the range of involved companies are limited. Nevertheless, this thesis is empirically founded by 124 domain experts within various companies covering different business areas. In detail, the empirical studies according to research complex I comprise 83 participants, the studies according to research complex II comprise 29 participants, and the studies according to research complex III comprise 12 participants.

4 Future Research

The utilization of smartwatches and smartwatch-based IS in the corporate context remains a promising topic. On the one hand, possible future research can address the limitations identified in the previous section and, on the other hand, can extend the domain of smartwatch-based information systems in the corporate context by continuing the work presented in this cumulative thesis. This is illustrated in Figure 60. Limitation L1 in future studies can be overcome by selecting an appropriate literature review scope according to the particular research's objectives. More general keywords like smartwatches result in a more detailed impression of the research domain, but the extent becomes quickly unfeasible, and the focus may be lost.



Execution of a long-term evaluation of *watchIT* in a broad range of companies including a large number of scenarios and employees.

Long-term impact of smartwatch-based IS, extending and substantiating the nascent design theory.

Socio-technical consequences like acceptance of novel IS, social structure of the workforce, and technostress.

Economic factors of the introduction of smartwatch-based IS in which the additional costs face the resulting benefits.

Execution of a long-term evaluation including a higher number of participating employees from a broader range of companies who can test the system in their daily life.

Extension of the *healthWatch* system exploiting more smartwatch sensors.

Investigate the potential of smartwatches to notify stationary employees trough the synchronization with extant IS.

Revision and extension of the *usabilityWatch* framework with additional approaches from the scientific literature and more practical application of the framework to existing smartwatch applications.

Consideration of hardware buttons and novel operating concepts of smartwatches.

Development of user interface design guidelines tailored for the corporate context based on scientific literature and the guidelines of *Google* and Apple.

Figure 60. Future research in the domain of smartwatch-based IS in the corporate context

To address the limitations that emerged in the **research complex I,** targeting smartwatch-based IS supporting mobile employees executing manual work, and to extend the scope of this domain, this thesis provides various connecting factors (top of Figure 60). Despite, the research within this research complex is extensive and covers plenty of representative use cases, there is potential for future research built on the findings of this thesis. The limitations are related to (L2) the scope of the investigated scenarios, (L3) the evaluation, and (L4) the number of design cycles. All three limitations can be addressed with an exhaustive practice-oriented field study that utilizes the *watchIT* smartwatch-based information system under realistic operating conditions. This study should involve a broad range of companies in different business sectors with a large number of participating employees for an exhausting evaluation and cover additional scenarios. To eliminate novelty effects, surveys should be conducted at the beginning and repeated after some time. If necessary, further design cycles can be conducted, and the presented design theory (Zenker et al. 2020a, study 4) can be further substantiated and confirmed. Besides addressing the limitations, additional aspects can be investigated. On the one hand, the long-term impact of smartwatch-based IS that provide a digital exchange of information and collaboration on the social level has to be investigated. This includes considerations of the workforce’s social structure and concomitants like the acceptance of novel technologies (Dutot et al. 2019) or technostress (Ayyagari et al. 2011). On the other hand, the economic consequences have to be quantified. Additional effort and costs for introducing such systems are counterbalanced by an increase in efficiency and consolidation of employees.

During the research documented in this cumulative thesis, two long-term studies have been planned, prepared, and elaborated on with a business partner. However, the experience showed that such studies require a considerable time-frame, particularly for the prearrangements, and there are various difficulties concerning organizational and technical aspects. An appropriate study under operating conditions necessitates the willingness of all participants who have to spend additional time during their daily work and deep interventions in the extant corporate systems. Despite considerable effort, these studies could not be completed within the scope of this thesis due to different reasons on the side of the business partner.

The limitations emerged in **research complex II** targeting smartwatch-based IS at the office workplace investigating corporate health promotion and possible extensions of the scope of this domain, offer various connecting factors (middle of Figure 60). To address limitations L5 and L6, a long-term evaluation including a higher number of participating employees and a more significant range of companies who can test the system in their daily life can be part of future studies. Hence, more universal requirements can be obtained. Furthermore, in this study, the questionnaires may be repeated after some time of experience to measure and purge the bias of novelty effects.

Besides, the functionality of *healthWatch* could be extended. For that, further gestures correlated to health, such as smoking or eating, can be elaborated. Furthermore, smartwatches offer counting sensors. Ambient light sensors can alert employees to ill light conditions for their eyes. Contact sensors can register the temperature and lead to a better working environment when the employees in the office suffer from heat or cold. Finally, microphones can be utilized to detect noise stress and promote a suitable work atmosphere. Since the basis has already been created, the extensions can be easily integrated into *healthWatch*. The values can be used to improve the occupational conditions.

Concluding the research complex II, studies according to smartwatches' ability to provide an incidental exchange of information and proactive notifications of employees through vibrations at their wrists should be conducted. Although employees can be digitally supported by stationary information systems, e.g., a desktop PC, there are approaches to augment interactions in an office environment (Bernaerts et al. 2014). Also, the study with employees from the quality assurance department within a production site suggested that stationary employees can benefit from the combination and synchronization of stationary, mobile and wearable devices (Zenker / Hobert 2019, study 1).

To address the limitations that emerged in **research complex III** targeting the usability of smartwatch applications and to extend the scope of this domain, this thesis provides various connecting factors (bottom of Figure 60). First, L7 and L8 can be addressed by a revision and extension of the *usabilityWatch* framework. On the one hand, the approaches of Zenker / Hobert (2020, study 6) can be complemented by an extensive literature review by identifying additional aspects for a dynamic usability analysis or other approaches finding evidence for usability deficits. On the other hand, the *usabilityWatch* framework should be applied to more smartwatch applications in order to improve the thresholds for the implemented metrics towards realistic values by expanding the practice and modularity as well as simplicity of the framework's integration into existing source code.

Second, due to the exclusion of hardware buttons so far and the continuous technical development of input capabilities like side-taps, brezel-buttons, wristband-swipes, or motion gestures (Zhang et al. 2016; Shimon et al. 2016), a framework for automatic usability analysis should be enhanced with the capability to involve such user interactions. This extension facilitates to overcome limitation L9.

Besides, the positioning and dimensions of the interactive elements like buttons in smartwatch user interfaces are a significant reason for usability issues caused by the small screen size (Khakurel et al. 2018; Hara et al. 2015; Da Tao et al. 2018). Furthermore, especially older employees may have problems with the delicate operation of small touchscreens (Lutze 2018). Hence, user interface design guidelines can be developed that describe smartwatch user interfaces from a usability view and complement the developer guidelines by Google (2020a) or Apple Inc. (2020a) based on usability research and knowledge about the user interface design of mobile information systems (Ayob et al. 2009; Ballantyne et al. 2018; Adipat / Zhang 2005; Rauch 2011).

Finally, this thesis demonstrated the potential of the utilization of smartwatch-based information systems in the corporate context. For that, especially the digital support of employees executing manual work was investigated, but this thesis also considered smartwatches at the office workplace. Besides, the usability of smartwatch applications was investigated as an important auxiliary tool for the development of smartwatch software. Smartwatches can thus be an essential part of the future of work and should hence be the focus of future research.

Appendix

1 Specifications of the Smartwatches Used in the Studies

	Operation System	**Display Size (Inch)**	**RAM (MB)**	**LTE Module**	**Battery Capacity (mAh)**
Huawei Watch 2	Android Wear 2.15	1.2	768	-	420
Fossil FTW4018	Wear OS 2.1	1.4	512	-	330
Skagen SKT5100	Wear OS 2.1	1.2	512	-	300
Diesel Full Guard 2.5 (DZT2008)	Wear OS 2.1	1.4	512	-	300

Table 34. Specifications of the used smartwatches

2 Interview Guideline of Production Study

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Interview Guideline
smartActivity - Utilization of Smartwatches in Production

Evaluation of a prototypical application for smartwatches to support workflows in companies.

Objective of the Interview

Evaluation of the implemented functionalities of the developed application *smartActivity* with the components

- Evaluation of the implemented functionalities of the developed application *smartActivity* with the components
    - smartwatch application
    - Web-based backend
- Identification of additional or missing functionalities

Structure of the Interview

(1) Entry of conversation
(2) Evaluation of the *smartActivity* application (front- and backend)
(3) Conclusion of the conversation

Approach

- Semi-structured
- Guideline-based

Target Group

Representatives from the industrial sector who have practical expertise in corporate workflows.

Part 1: Entry of Conversation

Welcome and introduction

- Welcoming the interview partners and thanking them for their willingness to participate
- Brief introduction of the interviewer
- Request for a short introduction of the interview partner(s)

Introduction to the research project

- Presentation of the contents and objectives of the research project
- If applicable, a brief explanation of the term smartwatches

Clarification of formal conditions

- Data protection and consent to the recording:
    - Of course, the information provided in this interview will be treated confidentially and is subject to this privacy policy
    - For evaluation purposes, I would like to record the interview. The audio recording will subsequently be transcribed and anonymized so that no conclusions can be drawn about you or your company. The evaluation of the interviews will be based on these anonymized transcripts for scientific purposes
      [If not already available, obtain data protection and consent declaration]
- Interview procedure
    - The interview will take about 30 minutes (max. 45 minutes). It is based on a variable list of questions. You are welcome to add your own questions or comments at any time.
    - Do you have any further questions about the content or procedure of the interview up to this point?
      [if you agree to the recording: start audio recording]

Part 2: Evaluation of *smartActivity*

[Prototype presentation]: Present prototype together with the use case live and provide explanations.

- How do you rate the existing functionalities of the *smartActivity* application?
    - Smartwatch application:
        - Display of open orders
        - Processing of an order
        - Notification of new orders
    - Web-based backend:
        - Overview of the most important key figures
        - Administration of workstations
        - Administration of orders
        - Management of processes and process steps (workflow editor)
- Is the utilization of the *smartActivity* application suitable for supporting employees in the execution of production process steps?
- Does the application solve the problems you formulated at the beginning of the current process flow?
- Can you imagine using it?
- Can you imagine other areas of application in the company?
- Are functionalities missing that would be useful for process support?
    - Smartwatch application
    - Web-based backend software
- How would you rate the usefulness of the application?
- How would you rate the ease of use of the application?
    - Interface design and input
    - Usability
    - Learnability
    - Sources of errors
- Do you see any adverse effects that could occur when using the smartwatch application?

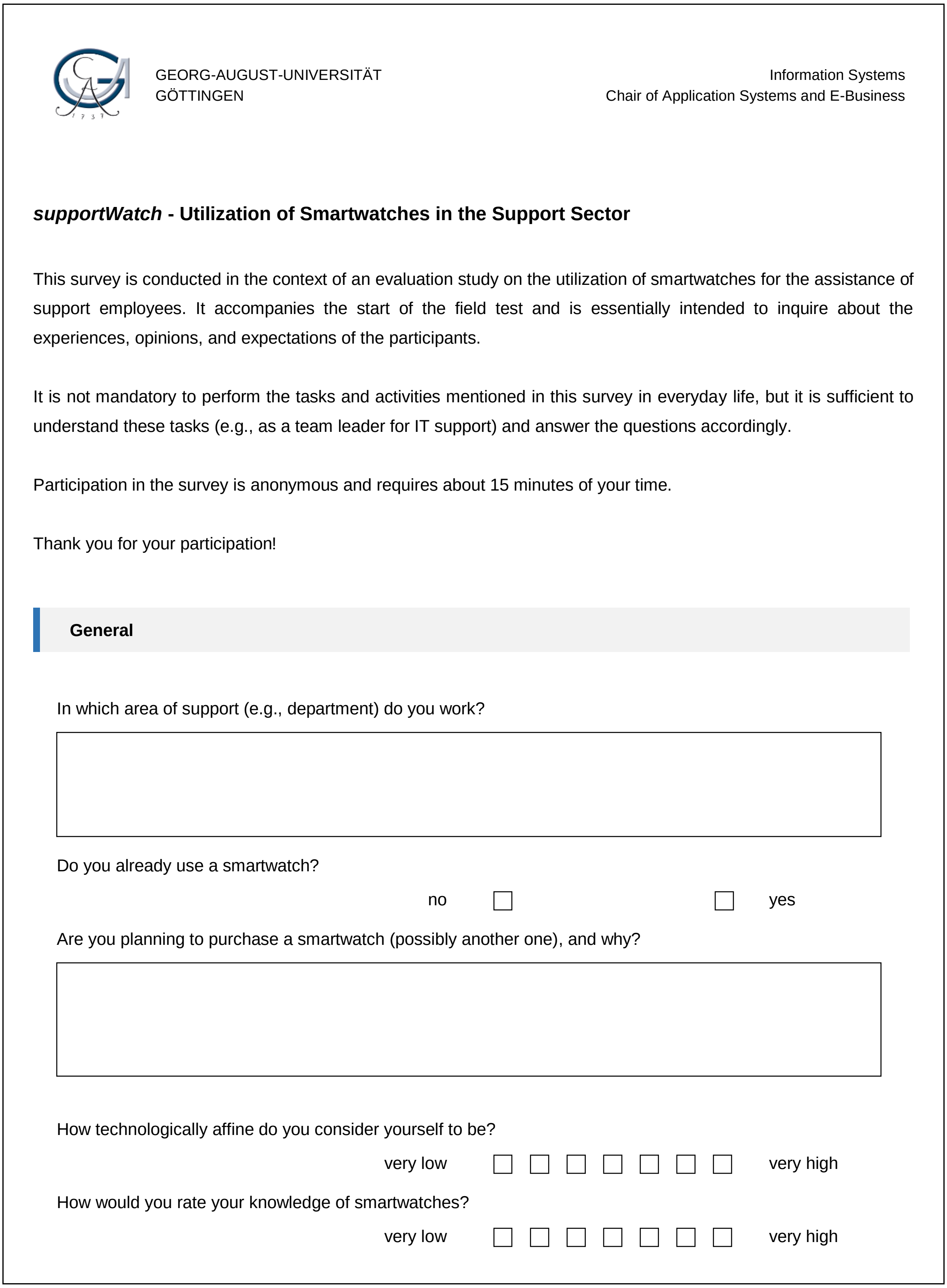
Part 3: Conclusion of the Conversation

Concluding remarks

- In closing, is there anything you would like to address? [then stop audio recording]
- Are you interested in the research results? If so, we will be happy to provide them to you upon completion of the study

Acknowledgments and farewell

3 Questionnaire and Interview Guideline of Support Study



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supportWatch - Utilization of Smartwatches in the Support Sector

This survey is conducted in the context of an evaluation study on the utilization of smartwatches for the assistance of support employees. It accompanies the start of the field test and is essentially intended to inquire about the experiences, opinions, and expectations of the participants.

It is not mandatory to perform the tasks and activities mentioned in this survey in everyday life, but it is sufficient to understand these tasks (e.g., as a team leader for IT support) and answer the questions accordingly.

Participation in the survey is anonymous and requires about 15 minutes of your time.

Thank you for your participation!

General

In which area of support (e.g., department) do you work?

Do you already use a smartwatch?

no ☐ ☐ yes

Are you planning to purchase a smartwatch (possibly another one), and why?

How technologically affine do you consider yourself to be?

very low ☐ ☐ ☐ ☐ ☐ ☐ ☐ very high

How would you rate your knowledge of smartwatches?

very low ☐ ☐ ☐ ☐ ☐ ☐ ☐ very high

What do you think about the fundamental idea of using smartwatches in an operational environment, and why?

Would you use your private smartwatch for your corporate tasks, and why?

Which concerns do you have about using a smartwatch for your tasks?

Concept

How do you rate the idea to …

… support your work and tasks with a smartwatch?

very bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ very good

… perform site inspections with the help of a smartwatch?

very bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ very good

… process tickets with the help of a smartwatch?

very bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ very good

… work with the presented system?

very bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ very good

What is your first overall impression of the presented system from the live demo?

very bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ very good

Functionalities

How do you rate the site management functionality of …

… sorting of the site list by the due date?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… a traffic light system to visualize the due date of a site inspection?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… location information?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… aligning the computers with the current inventory?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… updating the date of the last test via smartwatch?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… creating tickets via smartwatch with rudimentary location information when rework is required?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

How do you rate the ticket processing functionality of …

… reading tickets or your note on the smartwatch?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… attaching rudimentary information to tickets via the smartwatch?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

… closing tickets via the smartwatch?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

Which features that you think are essential for an evaluation are you missing?

Expectations

Do you expect that the utilization of the smartwatch is useful in the area of site inspections?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very usefull

Why do you expect that the utilization of the smartwatch is useful in the area of site inspections?

Do you expect that the utilization of the smartwatch is useful in the area of ticket processing?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very usefull

Why do you expect that the utilization of the smartwatch is useful in the area of ticket processing?

How do you expect that the utilization of the smartwatch affects the data quality (being up-to-date) during site inspections?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch affects the data quality (information content) during ticket processing?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch affects the speed of processing site inspections?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch affects the speed of processing tickets?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch affects the effort of site inspections?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch affects the effort of processing tickets?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of a smartwatch affects the use of the notebook …

… for site inspections?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

… for ticket processing?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

… and (still) have to write down my tasks on another medium?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

What is the effect of the utilization of a smartwatch concerning the extant systems?

How do you expect that the utilization of the smartwatch effects required rework (e.g., data maintenance or information transfer) for site inspections?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

How do you expect that the utilization of the smartwatch effects required rework (e.g., data maintenance or information transfer) for ticket processing?

decrease ☐ ☐ ☐ ☐ ☐ ☐ ☐ increase

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Interview Guideline
Utilization of Smartwatches in Support

This interview guideline is a component of the evaluation study investigating the utilization of smartwatches for the assistance of support and maintenance employees.

Objective of the Interview

The information obtained will contribute significantly to the investigation and evaluation of the utilization of smartwatches for process support in the maintenance of the university's IT infrastructure.

Structure of the Interview

(A) Entry of conversation
(B) Questions concerning the application areas
(C) Questions concerning the framing conditions
(D) Questions concerning the surveillance of employees
(E) Conclusion of the conversation
(F) Farewell

Approach

- Semi-structured
- Guideline-based

Target Group

Domain experts that have participated in the field study and actively have used the smartwatch during their work.

Part A: Entry of Conversation

Welcome and introduction

- Welcoming the interview partners and thanking them for their willingness to participate
- Create a pleasant atmosphere for conversation: offer small talk and, e.g., coffee/water

Introduction to the research project

- This work aims to gather insights on how smartwatches can be utilized for process support in the maintenance of the university's IT-infrastructure
- The interview is the conclusion of the field study in which you were actively involved
- In this context, I would like to talk with you about the experiences you have had in the last few weeks regarding the smartwatch and *smartActivity*

Clarification of formal conditions

- Data protection and consent to the recording:
  - Of course, the information provided in this interview will be treated confidentially and is subject to this privacy policy
  - For evaluation purposes, I would like to record the interview. The audio recording will subsequently be transcribed and anonymized so that no conclusions can be drawn about you or your company. The evaluation of the interviews will be based on these anonymized transcripts for scientific purposes
    [If not already available, obtain data protection and consent declaration]
- Interview procedure
  - The interview will take about 30 minutes (max. 45 minutes). It is based on a variable list of questions. You are welcome to add your own questions or comments at any time.
  - Do you have any further questions about the content or procedure of the interview up to this point?
    [if you agree to the recording: start audio recording]

Part B: Questions Concerning the Application Areas

- How did you use *smartActivity* during the field study?
- Which functions of *smartActivity* did you use during the field study?
- How did you use the smartwatch?
- Were the identified problems reduced or eliminated by *smartActivity* and why?
- Did you have to use other devices such as notebook/smartphone less frequently or not at all due to the use of the smartwatch in the field, and why?
- How did *smartActivity* support your work?
- How has work changed as a result of *smartActivity*?
- Were there any positive or negative effects of using *smartActivity*?
- What other areas of use can you imagine within your field of work?

Part C: Questions Concerning the Framing Conditions

- What did you generally like and dislike about using *smartActivity* and the smartwatch in particular?
- What conditions do you personally require in order to be able to use the smartwatch?
- Were there any technical problems during use, and if so, what were they?
- To what extent are smartwatches suitable for process support?
- Which smartwatch model did you use?
- What did you find particularly good or bad about the smartwatch?
- Is it essential for you to participate in influencing the choice of the smartwatch?
- From a technical and organizational perspective, what changes would you see as improvements for long-term use?

Part D: Questions Concerning the Surveillance of Employees

- Were you motivated by the field study to use the smartwatch in your free time as well?
- Did you have the impression of being monitored or controlled through the use of *smartActivity*?
- Did you feel restricted in your freedom of work?

Part E: Conclusion of the conversation

- Did you tell friends about the field study, or were you approached about the smartwatch?
- Finally, is there anything else you would like to talk about?
- In your opinion, is *smartActivity* suitable in principle for practical use, or what needs to be changed?

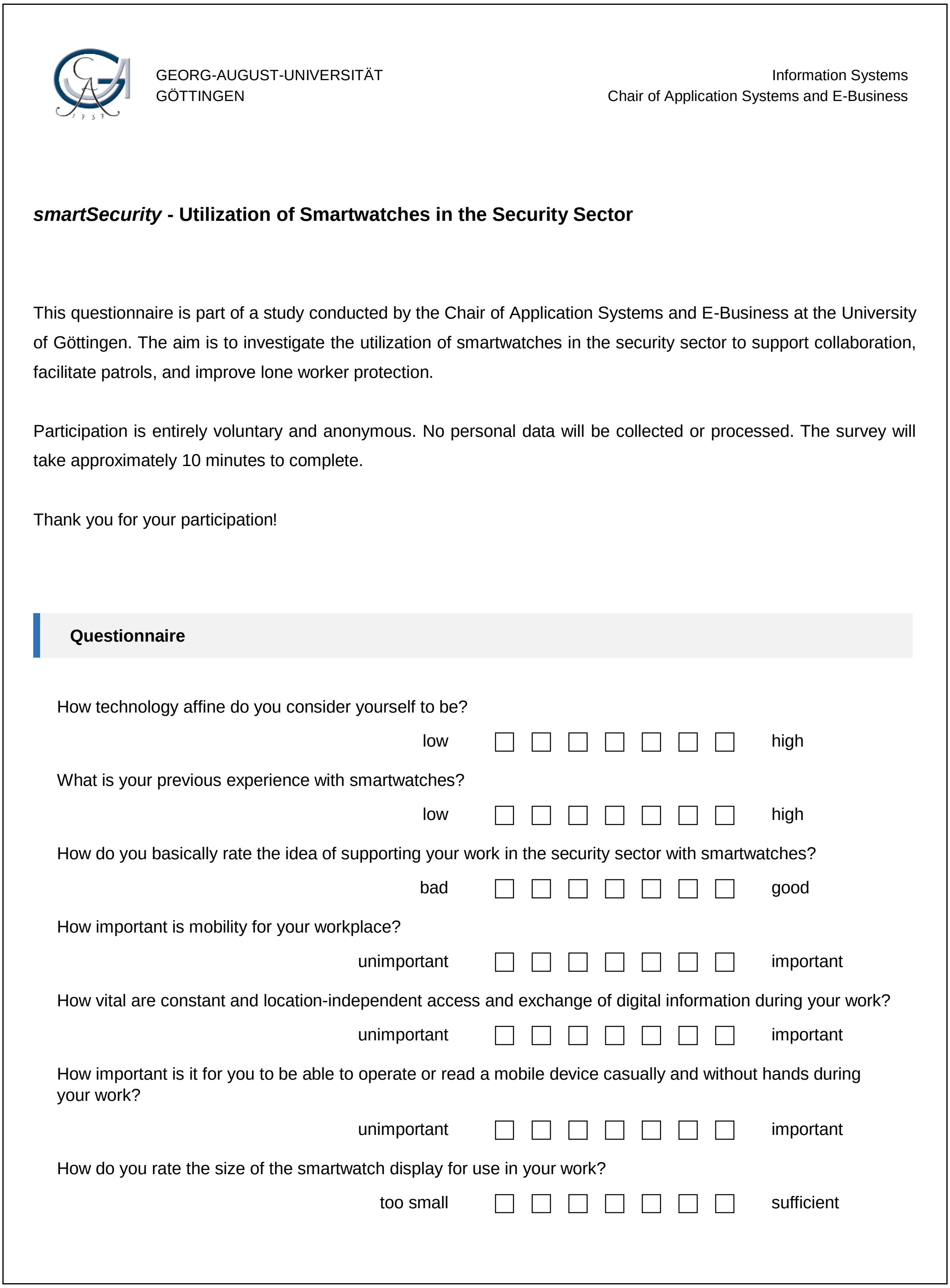
[stop recording]

Part F: Farewell

Acknowledgments for participation in the field study and interview.

Farewell.

4 Questionnaire of Security Service Study



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smartSecurity **- Utilization of Smartwatches in the Security Sector**

This questionnaire is part of a study conducted by the Chair of Application Systems and E-Business at the University of Göttingen. The aim is to investigate the utilization of smartwatches in the security sector to support collaboration, facilitate patrols, and improve lone worker protection.

Participation is entirely voluntary and anonymous. No personal data will be collected or processed. The survey will take approximately 10 minutes to complete.

Thank you for your participation!

Questionnaire

How technology affine do you consider yourself to be?

low ☐ ☐ ☐ ☐ ☐ ☐ ☐ high

What is your previous experience with smartwatches?

low ☐ ☐ ☐ ☐ ☐ ☐ ☐ high

How do you basically rate the idea of supporting your work in the security sector with smartwatches?

bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ good

How important is mobility for your workplace?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

How vital are constant and location-independent access and exchange of digital information during your work?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

How important is it for you to be able to operate or read a mobile device casually and without hands during your work?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

How do you rate the size of the smartwatch display for use in your work?

too small ☐ ☐ ☐ ☐ ☐ ☐ ☐ sufficient

Do you think the use of smartwatches will change the way you interact (e.g., verbal communication) with colleagues?

little change ☐ ☐ ☐ ☐ ☐ ☐ ☐ high change

How often do you think you can operate without a smartphone when using a smartwatch-based system?

rare ☐ ☐ ☐ ☐ ☐ ☐ ☐ frequent

How important do you think it is to have your workflows supported by a digital system?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

What advantages do you expect to see in the use of smartwatches in your day-to-day work?

What concerns do you have about the use of smartwatches in the security sector?

How useful do you perceive the functions ...

... for collaborative work between mobile and stationary employees via the smartwatch application or the web backend?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... forward tasks to employees and receive them without using your hands?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... be able to send voice messages (as a report)?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... to be able to contact colleagues via push-to-talk on the smartwatch?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... scan NFC tags at checkpoints without the need to get a device out of your pocket?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... record the issue and return of keys and equipment via the smartwatch by scanning?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... to have an overview of the checkpoints to be visited next, available on your wrist?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... to be navigated to the next checkpoint?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... create and customize routes and checkpoints individually?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... to be able to call for reinforcements quickly (with a gesture)?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... that an automatic emergency call is issued in the case of attacks or accidents?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

... that emergency calls are immediately reported to the security supervisor and colleagues?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

What is your overall impression of the presented system?

little useful ☐ ☐ ☐ ☐ ☐ ☐ ☐ very useful

What weaknesses do you identify in the system presented, and how could they be addressed?

If you had three wishes, what additional functions would you like to see for your work?

Which three features did you like most in the presented system and why?

Where do you see the advantages of a smartwatch-based system over a smartphone-based system?

How much could a smartwatch-based system make your daily work routine easier?

little ☐ ☐ ☐ ☐ ☐ ☐ ☐ much

How important do you think it is to have a voice in choosing the smartwatch model and wristband?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

What requirements should be met for the use of a smartwatch in your company?

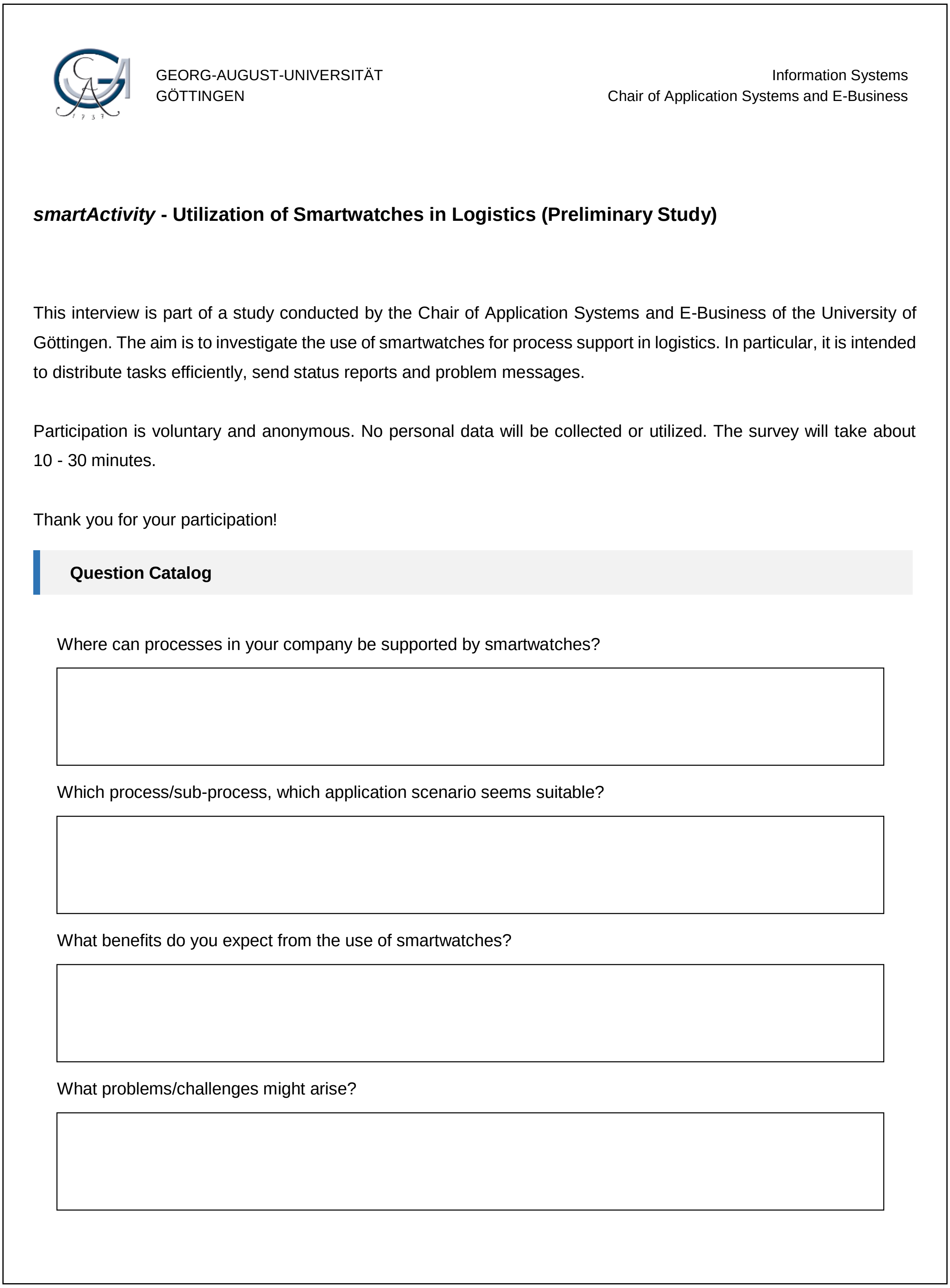
How worried are you about surveillance and tracking through a smartwatch?

low ☐ ☐ ☐ ☐ ☐ ☐ ☐ high

How interested are you in using the presented system to support your daily work?

unimportant ☐ ☐ ☐ ☐ ☐ ☐ ☐ important

5 Questionnaires and Workshop Guideline of Logistics Study



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Information Systems
Chair of Application Systems and E-Business

smartActivity - Utilization of Smartwatches in Logistics (Preliminary Study)

This interview is part of a study conducted by the Chair of Application Systems and E-Business of the University of Göttingen. The aim is to investigate the use of smartwatches for process support in logistics. In particular, it is intended to distribute tasks efficiently, send status reports and problem messages.

Participation is voluntary and anonymous. No personal data will be collected or utilized. The survey will take about 10 - 30 minutes.

Thank you for your participation!

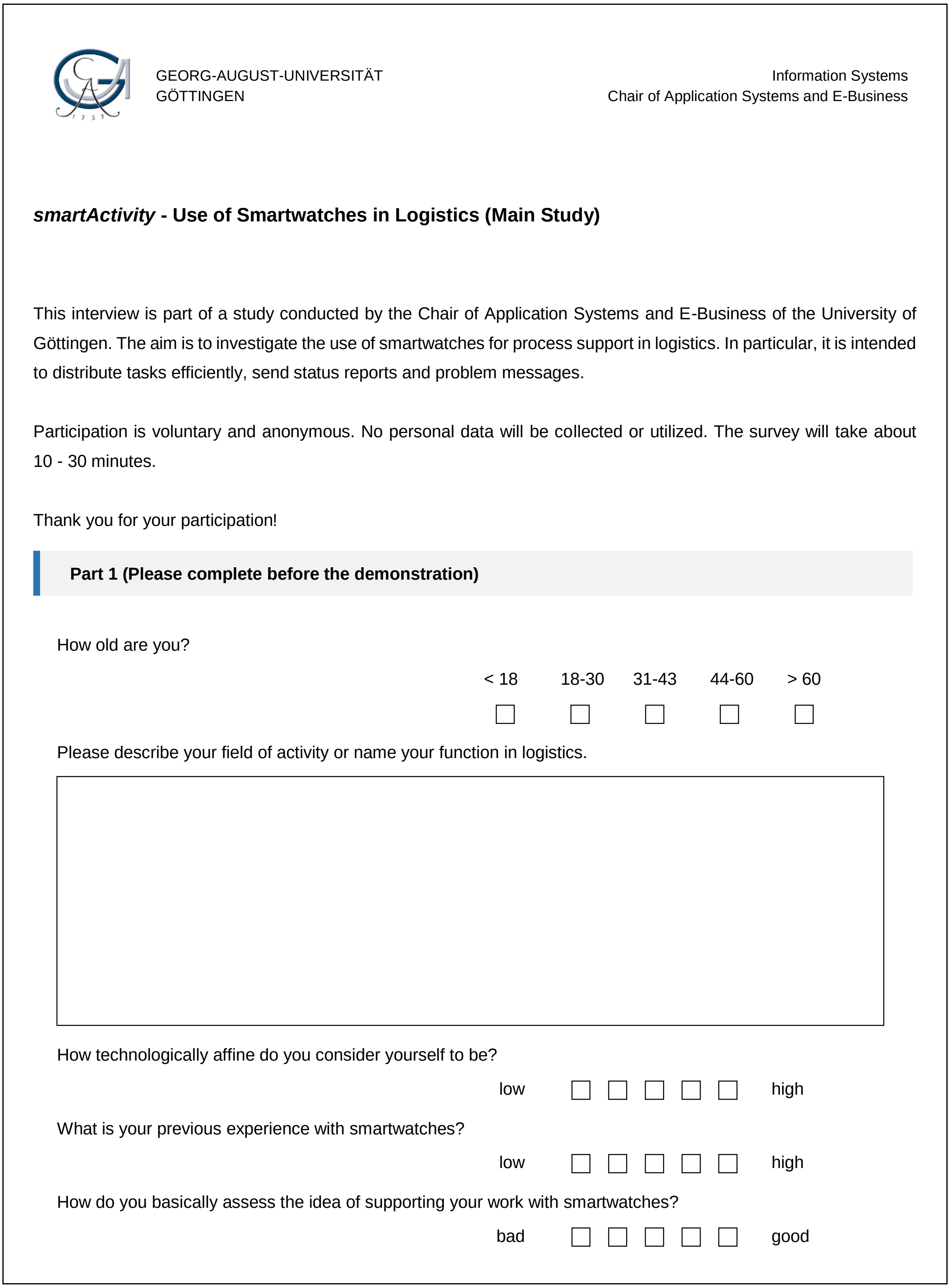
Question Catalog

Where can processes in your company be supported by smartwatches?

Which process/sub-process, which application scenario seems suitable?

What benefits do you expect from the use of smartwatches?

What problems/challenges might arise?



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Information Systems
Chair of Application Systems and E-Business

smartActivity - Use of Smartwatches in Logistics (Main Study)

This interview is part of a study conducted by the Chair of Application Systems and E-Business of the University of Göttingen. The aim is to investigate the use of smartwatches for process support in logistics. In particular, it is intended to distribute tasks efficiently, send status reports and problem messages.

Participation is voluntary and anonymous. No personal data will be collected or utilized. The survey will take about 10 - 30 minutes.

Thank you for your participation!

Part 1 (Please complete before the demonstration)

How old are you?

< 18	18-30	31-43	44-60	> 60
☐	☐	☐	☐	☐

Please describe your field of activity or name your function in logistics.

How technologically affine do you consider yourself to be?

low ☐ ☐ ☐ ☐ ☐ high

What is your previous experience with smartwatches?

low ☐ ☐ ☐ ☐ ☐ high

How do you basically assess the idea of supporting your work with smartwatches?

bad ☐ ☐ ☐ ☐ ☐ good

Part 2 (Please complete after the demonstration)

How do you rate the size of the smartwatch display for use in your field of activity?

too small ☐ ☐ ☐ ☐ ☐ sufficient

How important do you think it is to have your workflows supported by a digital system?

unimportant ☐ ☐ ☐ ☐ ☐ important

How useful do you perceive the functions...

...for the cooperation between the team leaders and the operational staff?

little useful ☐ ☐ ☐ ☐ ☐ very useful

...forward tasks to colleagues and receive them?

little useful ☐ ☐ ☐ ☐ ☐ very useful

...for multilingualism?

little useful ☐ ☐ ☐ ☐ ☐ very useful

What is your overall impression of the presented prototype?

little useful ☐ ☐ ☐ ☐ ☐ very useful

What advantages do you expect to see in the use of smartwatches in your daily work?

What concerns do you have about using smartwatches in your daily work?

What weaknesses do you identify in the presented system, and how could they be addressed?

If you had three wishes, what additional functions would you desire for your work?

Which features did you particularly appreciate in the presented system and why?

How much could the presented system facilitate your everyday work?

little ☐ ☐ ☐ ☐ ☐ much

How important do you think it is to have a voice in selecting the smartwatch model and its wristband?

unimportant ☐ ☐ ☐ ☐ ☐ important

What requirements should be met for the use of a smartwatch in your company?

How much do you fear being monitored and tracked by a smartwatch?

low ☐ ☐ ☐ ☐ ☐ high

How interested are you in using the presented system to support your daily work?

low ☐ ☐ ☐ ☐ ☐ high

What other possible uses do you see for the smartwatch in logistics?

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smartActivity **- Use of Smartwatches in Logistics (Workshop Guideline)**

Evaluate and demonstrate the *smartActivity* application and ask employees about further requirements for this application, including the release of orders by team leaders and problem and status messages in logistics processes.

Objective of the Presentation

- Demonstration of the prototype
- Evaluation of the *smartActivity* application
- Identification of further requirements from the logistics domain

Structure of the Workshop

(1) Entry of conversation
(2) Presentation of the application
(3) Conclusion of the conversation

Approach

- Guideline-oriented
- Questionaire-oriented
- Semi-structured

Target Group

Employees from the company's incoming goods, outgoing goods, and cross-docking departments (operational employees), as well as managers.

Part 1: Entry of Conversation

Welcome and introduction

- Welcoming the participant(s) and thanking them for their willingness to participate.

Clarification of formal conditions

- The information provided in this presentation will be treated confidentially
- The data is anonymized
- The presentation lasts about 20-30 minutes. Questions or comments can be expressed at any time, apart from the questionnaire

Introduction to the research project

- Request to answer the first part of the questionnaire

After response time (maximum five minutes)

- Presentation of the objective and contents of the research project
- A brief explanation of the term smartwatch
- A brief explanation of the recent findings (results of the preliminary survey and resulting requirements for the utilization of smartwatches in logistics)

Part 2: Presentation of the Application

Procedure

- The application will be presented using a simulated scenario. The duration will be a maximum of 10 minutes.
- Request to answer the second part of the questionnaire after the demonstration

Part 3: Conclusion of the Conversation

Concluding remarks

- Is there anything else you would like to add or discuss?
- Do you have any suggestions for improving the course of the presentation or the questionnaire?
- If you wish, the results of the research project can be made available for you afterward

Acknowledgments and farewell

6 Detailed Statistics of Health Promotion Study

<table>
<tr><th>Block</th><th colspan="2">Item</th><th>Type</th><th>M</th><th>SD</th><th>Source</th></tr>
<tr><td rowspan="7">1</td><td colspan="2">I like to occupy myself in greater detail with technical systems.</td><td>QN</td><td>5.07</td><td>1.69</td><td>ATI-S</td></tr>
<tr><td colspan="2">How much experience do you have with smartwatches?</td><td>QN</td><td>2.62</td><td>2.09</td><td rowspan="6"></td></tr>
<tr><td colspan="2">How would you rate the idea of supporting corporate health management with smartwatches?</td><td>QN</td><td>4.55</td><td>1.97</td></tr>
<tr><td colspan="2">How important is the incidental collection of data by sensors that you wear anyway?</td><td>QN</td><td>3.72</td><td>2.07</td></tr>
<tr><td colspan="2">How important do you think it is to have your health supported by a digital system?</td><td>QN</td><td>3.83</td><td>1.77</td></tr>
<tr><td colspan="2">What benefits do you consider when smartwatches are used in the context of health management?</td><td>QL</td><td colspan="2">--</td></tr>
<tr><td colspan="2">What concerns do you have about using Smartwatches in the context of health management?</td><td>QL</td><td colspan="2">--</td></tr>
<tr><td rowspan="5">2</td><td colspan="2">How useful do you find the <i>following</i> features of the application?</td><td rowspan="2">QN</td><td colspan="2" rowspan="2"><i>see
Table 36</i></td><td rowspan="5"></td></tr>
<tr><td><i>Features</i></td><td><i>Onboarding, dashboard, pulse data, step data, drink frequency, mood setting, courses & tips,
self-assessment, notifications</i></td></tr>
<tr><td colspan="2">Which three functions did you particularly like in the system and why?</td><td>QL</td><td colspan="2">--</td></tr>
<tr><td colspan="2">Which weaknesses did you identify in the system, and how could they be eliminated?</td><td>QL</td><td colspan="2">--</td></tr>
<tr><td colspan="2">What advantages do you see in the gamified, smartwatch-based system compared to conventional fitness trackers?</td><td>QL</td><td colspan="2">--</td></tr>
<tr><td rowspan="2">3</td><td colspan="2">How much would the <i>following</i> features motivate you to participate in health-promoting activities?</td><td rowspan="2">QN</td><td colspan="2" rowspan="2"><i>see
Table 37</i></td><td rowspan="2"></td></tr>
<tr><td><i>Features</i></td><td><i>Daily quests, team quests, leaderboard, badges,
points & level, profile, avatar, performance graphs</i></td></tr>
<tr><td rowspan="8">4</td><td colspan="2">I think using the system would be interesting for me.</td><td>QN</td><td>4.45</td><td>1.88</td><td rowspan="8">IMI
&
TAM</td></tr>
<tr><td colspan="2">I think using the system would be entertaining for me.</td><td>QN</td><td>4.79</td><td>1.63</td></tr>
<tr><td colspan="2">I think using the system would be helpful for me to become more satisfied with my health.</td><td>QN</td><td>4.24</td><td>1.66</td></tr>
<tr><td colspan="2">I think using the system would promote my health competence.</td><td>QN</td><td>4.38</td><td>1.50</td></tr>
<tr><td colspan="2">I think using the system would put me under pressure.</td><td>QN</td><td>4.21</td><td>1.52</td></tr>
<tr><td colspan="2">I think I would use the system voluntarily.</td><td>QN</td><td>4.28</td><td>1.83</td></tr>
<tr><td colspan="2">I think I would like to interact more often with other colleagues via the system.</td><td>QN</td><td>3.41</td><td>1.66</td></tr>
<tr><td colspan="2">I think I would feel connected with the other colleagues while using the system.</td><td>QN</td><td>3.66</td><td>1.49</td></tr>
</table>

	I find the feedback of the gamified, smartwatch-based platform informative.	QN	5.45	0.99	
	I felt surveilled as a user of the gamified, smartwatch-based platform.	QN	4.71	1.84	
M = Mean; SD = Standard deviation; QN = Quantitative item; QL = Qualitative item; ATI = Affinity for Technology Interaction (Franke et al. 2019); IMI = Intrinsic Motivation Inventory (Deci et al. 1994); TAM = Technology Acceptance Model (Davis et al. 1989);					

Table 35. Structure of online questionnaire with descriptive statistics

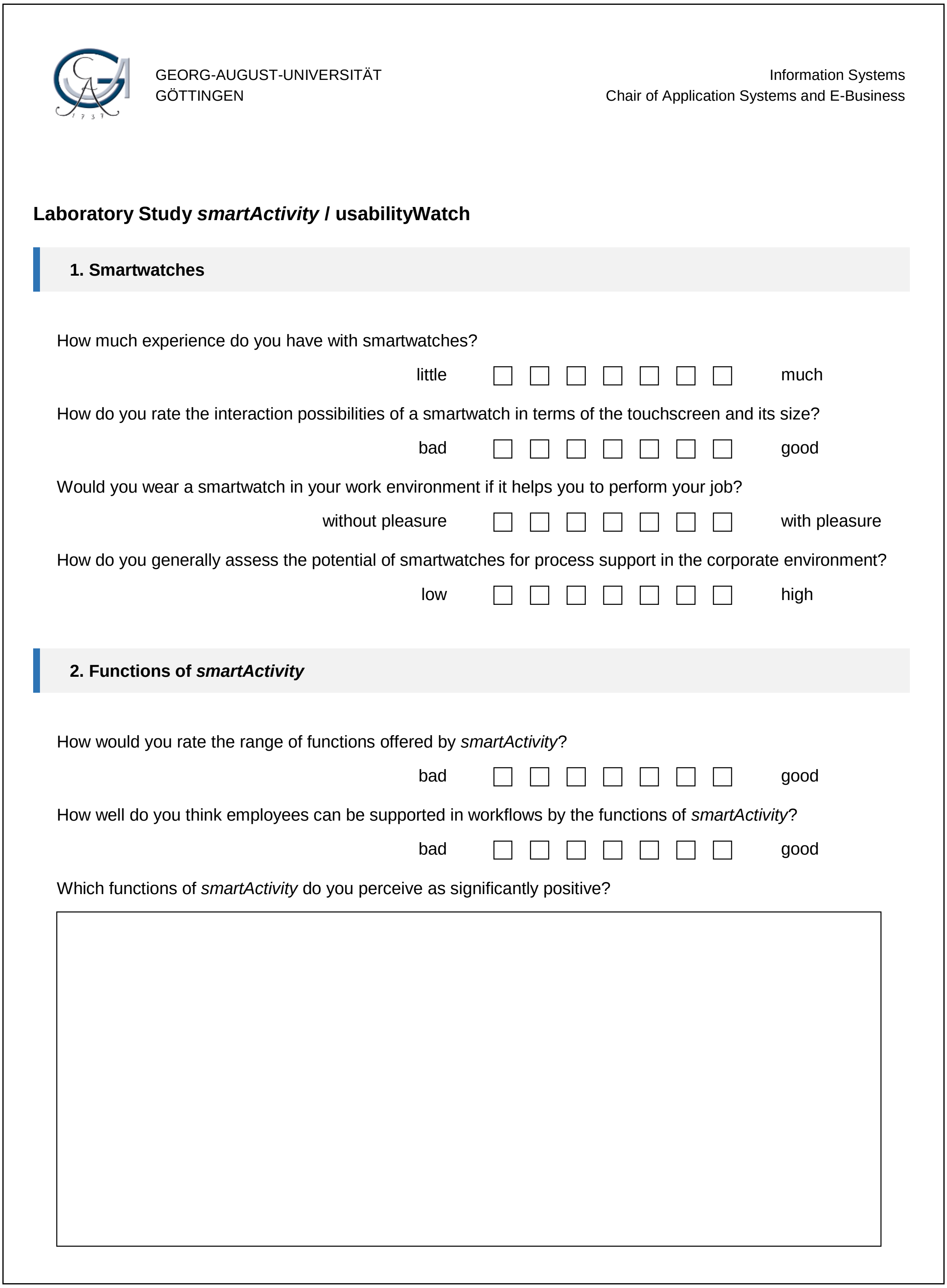
Rank	**How useful do you find the *following* features of the application?**	**M**	**SD**	**SK**	**RKU**
1	Dashboard	6.24	1.27	-2.84	10.0
2	Step data	5.83	1.26	-2.09	6.88
3	Notifications	5.62	1.37	-0.49	-1.16
4	Onboarding	5.41	1.96	-1.03	-0.41
5	Courses & Tips	5.17	1.51	-0.65	0.38
6	Pulse data	5.00	1.77	-1.03	0.65
7	Drink frequency	4.79	1.97	-0.65	-0.61
8	Self-assessment	3.62	1.61	-0.10	-0.54
9	Mood setting	3.10	1.61	0.10	-1.43
M = Mean; SD = Standard deviation; SK = Skewness; RKU = Kurtosis					

Table 36. Ranking of features based on mean of participants perceived usefulness

Rank	**How much would the *following* features motivate you to participate in health-promoting activities?**	**M**	**SD**	**SK**	**RKU**
1	Performance graphs	4.79	1.78	-0.93	0.20
2	Daily quests	4.48	1.84	-0.48	-0.60
3	Team quests	3.93	1.96	-0.02	-1.47
4	Points & levels	3.76	1.66	-0.24	-0.77
5	Badges	3.52	1.72	0.24	-0.84
6	Leaderboard	3.52	1.92	0.30	-1.40
7	Profiles	2.90	1.78	0.53	-0.99
8	Avatars	2.69	1.67	0.53	-1.20
M = Mean; SD = Standard deviation; SK = Skewness; RKU = Kurtosis					

Table 37. Ranking of features based on mean of participants perceived motivational effect

7 Questionnarie of Usability Study



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Laboratory Study *smartActivity* / usabilityWatch

1. Smartwatches

How much experience do you have with smartwatches?

little ☐ ☐ ☐ ☐ ☐ ☐ ☐ much

How do you rate the interaction possibilities of a smartwatch in terms of the touchscreen and its size?

bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ good

Would you wear a smartwatch in your work environment if it helps you to perform your job?

without pleasure ☐ ☐ ☐ ☐ ☐ ☐ ☐ with pleasure

How do you generally assess the potential of smartwatches for process support in the corporate environment?

low ☐ ☐ ☐ ☐ ☐ ☐ ☐ high

2. Functions of *smartActivity*

How would you rate the range of functions offered by *smartActivity*?

bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ good

How well do you think employees can be supported in workflows by the functions of *smartActivity*?

bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ good

Which functions of *smartActivity* do you perceive as significantly positive?

Which functions did you miss in *smartActivity* or should be added?

3. Usability of *smartActivity*

How would you rate the learnability of *smartActivity*?

difficult ☐ ☐ ☐ ☐ ☐ ☐ ☐ easy

How would you rate the usability of *smartActivity*?

bad ☐ ☐ ☐ ☐ ☐ ☐ ☐ good

Has the use of *smartActivity* led to many operating errors?

many ☐ ☐ ☐ ☐ ☐ ☐ ☐ few

How much does the number of required interactions interfere with the actual manual work?

very ☐ ☐ ☐ ☐ ☐ ☐ ☐ little

Which usability aspects of *smartActivity* did you perceive as significantly positive?

What problems did you encounter when using *smartActivity,* and what weaknesses did you perceive?

4. Concluding Remarks

Are there any other comments?

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Steffen Zenker

Overview of Author Contribution Ratios of the Thesis Paper

Outlet	Authors		Contribution
Study 1: Design and Implementation of a collaborative Smartwatch Application Supporting Employees in Industrial Workflows (Zenker / Hobert 2019, study 1)			
ECIS 2019 (published)	**Zenker** Hobert	**85 %** 15 %	conceptualization, software, investigation (interviews and workshop), data analysis, writing, visualization
Study 2: The Smartwatch Applicability Framework: Adoption of a Smartwatch-based Information System Assisting Support Employees (Zenker et al. 2020b, study 2)			
ECIS 2020 (published)	**Zenker** Rach Hobert	**85 %** 10 % 5 %	conceptualization, methodology, software supervision, investigation (interviews), data analysis, writing, visualization
Study 3: Utilizing a Smartwatch-based System to Support Security Service Employees (Zenker 2020, study 3)			
AMCIS 2020 (published)	**Zenker**	**100 %**	conceptualization, methodology, software, investigation (interviews, questionnaires, workshops), data analysis, writing, visualization
Study 4: Designing Smartwatch-based Information Systems to Support Mobile Employees Executing Manual Work (Zenker et al. 2020a, study 4)			
under review	**Zenker** Hobert Schumann	**90 %** 5 % 5 %	conceptualization, methodology, software, investigation (online laboratory experiment and online questionnaire), data analysis, writing, visualization
Study 5: Promoting Health at Office Workplaces with a Gamified and Smartwatch-based Information System (Wesseloh et al. 2020b, study 5)			
under review	Wesseloh **Zenker** Jokisch Niemeyer Schumann	40 % **35 %** 10 % 10 % 5 %	conceptualization, methodology, software supervision, investigation, writing (predominantly smartwatch- and system-related)
Study 6: Design and Implementation of a Usability-Framework for Smartwatches (Zenker / Hobert 2020, study 6)			
HICSS 2020 (published, best paper nominee)	**Zenker** Hobert	**95 %** 5 %	conceptualization, methodology, software, investigation (laboratory experiment and questionnaires), data analysis, writing, visualization

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