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Digitizing Health Care Processes using Augmented Reality Mobile Health Applications

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Preface

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First of all, I would like to thank my Ph.D. advisor Prof. Dr. Helmut Krcmar, who acted as a strong tailwind throughout my time at the chair. Be it by personally delivering the newest smart glass technologies to my office, months before they were available on the German market, or by giving me valuable guidance on how to write difficult book chapters. Your approach to leading a large chair and working with industry has taught me many valuable lessons. Moreover, I would like to thank Prof. Dr. Manuel Wiesche, who was my research group leader during my time at the chair and helped to shape and sharpen many of my research projects. Next, I deem myself very lucky to have met Prof. Dr. Jason Thatcher. I learned a lot from you and will always admire your humble and selfless approach to helping others. Last but not least, I would like to thank our secretary, Andrea Trost. You always had an open ear and helped me find pragmatic solutions for things I did not know how to solve.

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Munich, August 2020 Kai Klinker

Abstract

Problem Statement: Digitization using smart glasses and augmented reality technology holds potential for supporting mobile service processes. In the past, the research focus regarding these technologies has been on technical aspects. However, smart glass and augmented reality technologies have emerged to a point where they are starting to become viable options for supporting service processes in real-world scenarios. This is especially true for the health care sector, where septic safe and hands-free use of technology is required. Smart glasses inhibit innate potential for this context because they can be operated hands-free and allow health care professionals access to information systems at the point of care. Yet, little research exists on how use cases for this emerging technology can be identified, evaluated, and implemented. Furthermore, it is unclear whether patients would opt-in to treatments involving smart glasses.

Research Design: To address these research gaps, we conducted a series of studies employing a range of quantitative, qualitative, and design science research methods. To address the first research question on the systematic identification of smart glass and augmented reality use cases, we conducted one study, which made use of ethnographies, focus groups, and interviews. For the second research question on the implementation of use cases, we conducted three studies. All of them employed design science approaches, and some made use of experimental designs, ethnographies, focus groups, or interviews to conduct relevance and design cycles. Finally, the third research question is focused on the patient perspective on the use of smart glasses in health care facilities. To address this research question, we conducted two studies in which one used interviews, and the other employed an experimental design using an online survey.

Results: Regarding the first research question on the systematic identification of use cases, we developed a taxonomy that clusters the use cases into several overarching themes. Furthermore, we proposed a framework that integrates smart glass technology into an existing task-technology fit framework for mobile technologies. Our main results pertaining to the second research question are project descriptions and design principles derived from our design science research on several use cases in different health care contexts. Amongst others, we propose design principles for hands-free technology interaction. Finally, regarding the influence of smart glasses on trusting relationships between health care professionals and patients, we derived some initial results. The two studies we conducted show that technological, as well as interpersonal aspects, play a role in this context. Interpersonal aspects align with Mayer's model of interpersonal trust, while the constructs of perceived usefulness and privacy concerns can be used to model technological aspects.

Contribution: Our results contribute, first, to the literature on smart glasses and augmented reality. By providing a taxonomy and frameworks for task-technology fit, we give practitioners and researchers in this domain tools that can help to identify and evaluate the potential of use cases systematically. Furthermore, the design science projects we conducted, in which we implemented individual use cases can serve as examples for digitization projects using smart glass and augmented reality technology. From these projects, we have derived design principles that can further guide in similar endeavors. Second, we contribute to the literature on trust in information systems by conducting exploratory research in the context of passive trust. For that, we

transfer and empirically evaluate models and constructs from the interpersonal trust and active trust in technology literature in the passive trust context.

Limitations: Several of our studies have limitations. Some of them are related to sample sizes or recruiting strategies for experiment participants. For example, in some studies, we used student samples. In another study, we relied on a recruiting strategy that yielded a very uneven gender distribution in our study. Furthermore, the generalizability of our results is limited to the context of the German health care system, as health care is a particular context, and health care systems can differ considerably among different countries.

Future Research: Our thesis yields four starting points for future research: First, throughout our research on systematic identifications of use cases, we noticed that data security is of central importance in many service industries. Thus, as smart glasses with their outward-facing cameras are a very pervasive technology, future research on privacy and ethical requirements are needed. Second, to digitally transform the health care sector and other service industries, identification of further use cases and design science research to implement these use cases is required. Third, the usage of smart glasses in smart service systems implies interesting options for artificial intelligence. Future work looking into technical aspects of combining smart glasses and augmented reality could help to deliver more value to smart glass users during service delivery. Finally, research on passive trust is still in a very early stage. Further research on this topic is important to derive guidelines for the use of smart glasses in service processes that involve passive users.

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List of Abbreviations

CON	Conference
ECIS	European Conference on Information Systems
EJIS	European Journal of Information Systems
EM	Electronic Markets
TEM	IEEE Transactions on Enginieering Management
HICSS:	Hawaii International Conference on System Sciences
ISF:	Information Systems Frontiers
DESRIST:	Conference on Design Science Research in Information Systems
TVCG:	IEEE Transactions on Visualization and Computer Graphics
MKWI:	Multikonferenz Wirtschaftsinformatik
IS	Information Systems
IT	Information Technology
P	Publication
RQ	Research question
VHB	German Academic Association for Business Research
WI	Internationale Tagung Wirtschaftsinformatik
WP	Working paper
ICT	Information and Communication Technology
POC	Point of Care
DoF	Degrees of Freedom
AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
2D	Two-dimensional
3D	Three-dimensional
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
TPB	Theory of planned behavior
PEOU	Perceived ease of use
PU	Perceived usefulness
BI	Behavioral intention
AU	Actual use

SI	Social influence
FC	Facilitating conditions
EE	Effort expectancy
PE	Performance expectancy
HM	Hedonic motivation
PV	Price value
H	Habit
CIT	Critical Incident Technique

Part A

1 Introduction

1.1 Motivation

Industrialized countries are experiencing a shift from production to services. 50% of jobs in Brazil, Russia, Japan, and Germany, as well as 75% of the labor force in the United States and the United Kingdom, are currently within the service sector (Han et al. 2013; Wang et al. 2015). Services make up around 70% of German economic output and are an essential facet of German companies' product portfolio (Hoffmann 2018). Due to the increasing international competition in the service sector, service quality and service innovations are becoming increasingly important for German companies (Barile/Polese 2010; Gleich et al. 2017). The use of innovative Information and Communication Technologies (ICT) such as smart glasses and Augmented Reality (AR) can help both customers and service providers to optimize services through service innovation and ensure future competitiveness (Dietrich/Schirra 2006).

ICTs can facilitate service innovation by playing a dual role, as both an operand (enabler) and an operant (initiator or actor) resource (Lusch/Nambisan 2015). ICTs are used in combination with other resources (such as skills and knowledge) to leverage information use across different contexts and to create new opportunities for service innovation (Barrett et al. 2015). Rapid development and widespread deployment of ICTs are fundamental to many service innovations (Barrett et al. 2015). However, established ICTs like smartphones and tablets have not yet achieved large-scale adoption in service industries like health care. One of the main reasons for this is, that employees often need both hands for their work, making it complicated to interact with the device during work (Czuszynski et al. 2015; Mitrasinovic et al. 2015).

AR smart glasses, such as the Microsoft HoloLens, are a new generation of smart devices that have the potential to transform service processes. Smart glasses augment their user's field of view with virtual information (Azuma 1997) and can complement or enhance service processes and workflows (Niemöller et al. 2017). They can be operated hands-free and do not hinder employees during their work while giving them access to an information system. Especially in situations where employees perform information-intensive activities while having to work hands-free, smart glasses can show context-sensitive information in the user's field of view and thereby support employees in their daily work routine (Huck-Fries et al. 2017a). The central potentials for ICT applications to support service processes are projected improvements of performance, process quality, employee satisfaction, and IT-enabled collaboration (Mitrasinovic et al. 2015). One of the main problems for current research on smart glasses is to identify use cases for this emerging technology (Herterich et al. 2015).

One service domain that inhibits high potential for digitization using smart glasses is the health care sector. As administrative burdens in health care have been increasing over the last years, health care professionals have less and less time for direct patient care tasks (Seto et al. 2014; Vollmer et al. 2014). Employing smart glasses to provide information access for health care professionals at the point of care (POC) is thus a promising path to improve outcomes and reduce administrative burdens (Rooij/Marsh 2016; Beverungen et al. 2017). Smart devices allow health care service providers to retrieve and analyze aggregated field data and to dynamically adapt service systems to the patients' needs (Beverungen et al. 2017). For many use cases, hands-free interaction with Information Systems (IS) is necessary (Afkari et al. 2014). Reasons for this can be that both hands are needed for work, hands are dirty or aseptic procedures need to be performed (Mewes et al. 2017).

Despite the potential smart glasses pose for digitization in the health care sector, very few examples and design principles for implementation of smart glass supported service processes exist. In the health care sector, smart glasses have been adopted in some useful applications including, hands-free photo and video documentation, telemedicine, Electronic Health Record retrieval and input, rapid diagnostic test analysis, education, and live broadcasting (Mitrasinovic et al. 2015; Klinker et al. 2018a; Huck-Fries et al. 2017b). Existing design principles for smart glasses in the scientific literature focus on improved social acceptability. For instance, some studies suggest that instead of designing all-purpose smart glasses, smart glass designs should instead focus on clear, task-oriented usage to allow users to see them as a dedicated aid in a specific work environment (Zhao et al. 2015). Also, knowledge about the intended use of smart glasses and the actions performed with the device is crucial when it comes to user acceptance since it helps to reduce concerns (Zhao et al. 2015).

Especially in the health care sector, research on the usage of smart glasses is still at a very early stage, and studies taking both, the patient and the health care worker's perspective are scarce (Strandås/Bondas 2018). A study by Prochaska et al. found that many patients had concerns about privacy, but very few expressed that it would affect their trust in a doctor (Prochaska et al. 2016). The patient perspective on the usage of smart glasses is especially vital in the health care domain because patients need a trusting relationship with their health care professionals to take medical advice from them (Strandås/Bondas 2018). The central role of interaction quality for evoking patient satisfaction has been recognized by numerous studies (Arab et al. 2012). It is easy to imagine that smart glasses might have adverse side effects on patient trust and interaction quality. Smart glasses can obscure parts of the health care worker's face or divert the patient's attention, which could negatively impact communication. Furthermore, most smart glasses have outward-facing cameras that are directed towards the patient. This might raise privacy concerns on the patient's side, impeding the overall acceptance of the technology.

In summary, a large body of scientific research exists on the technical aspects of AR and smart glasses. Yet, there is little research on the systematic identification of use cases for these technologies in existing service domains. Furthermore, very few recommendations in the form of design principles or practical examples exist that would suit as guidance for implementing AR or smart glass applications that support employees during service delivery. This is especially true for the health care sector, a domain with unique challenges and opportunities for digitization using hands-free technologies. Finally, acceptance of AR smart glass technologies does not only depend on perceptions of the person wearing the smart glasses but also on the social acceptability of bystanders. This allows us to formulate three fundamental challenges that have not been addressed in extant IS research:

First, the scientific discussion on AR and smart glass technology has mainly taken place in computer science conferences and journals and has focused on topics related to technical feasibility. Yet, the field is advancing from a focus on enabling technologies such as tracking algorithms and efficient onboard GPUs towards research on how AR and smart glass technologies can be applied to support service processes in real-world settings. We argue that at this point, smart glasses and AR research can benefit from a strength of IS research, which is to see technical artifacts in their socio-economical context. Using models, frameworks, and theories from the IS domain can help to find systematic approaches to use case identification in various service industries.

Second, very few practical examples and recommendations exist for the development of AR and smart glass applications. To advance the status quo, design science research, one of the core disciplines of IS, can be used to generate descriptive and prescriptive design knowledge. Such knowledge can take the form of instantiations, constructs, methods, models, technological rules, or design theories (Gregor/Hevner 2013). Design recommendations derived using design science research are needed to facilitate AR and smart glass development and to increase acceptance of solutions in various service domains.

Third, trust research is one of the IS core research topics (Söllner et al. 2016). Regarding smart glasses, the subtopics of interpersonal trust and trust in technology are of particular interest. Interestingly there is a research gap in the IS literature regarding the passive use of technology. Passive users are individuals who are not in direct control of a technology but who are nonetheless affected by outcomes that are produced by an active user's use of the technology (Lee et al. 2015). As the trust in technology literature assumes the perspective of an active technology user, constructs and models used to predict active trust need to be transferred to the passive context. Moving constructs and models to the passive context can help to derive insights into what factors need to be taken into account in order to develop smart glass applications that are acceptable to passive users.

1.2 Research Questions

The overall objective of this thesis is to build an understanding of how use cases for AR and smart glasses can be identified and implemented. As outlined in the introduction, the domain of health care is a promising field of application, which is why we have devoted the focus of our efforts to this domain. We will answer three research questions within this thesis:

RQ1: *How can use cases for augmented reality smart glass applications in health care be identified systematically?*

This question can be answered by contextualizing existing theories on cognitive load and task-technology fit using experimental designs. Further, bottom-up approaches categorizing different use cases into a taxonomy can help to provide a structured overview.

RQ2: *What design recommendations can be deduced for mobile health applications?*

Based on use cases identified in our work on RQ1 and guided by this research question, we aim to conduct design science research on several use cases to derive prescriptive design knowledge. The insights gained throughout these projects will be used to propose recommendations in the form of design principles that can be used by researchers and practitioners in future work.

RQ3: *How does health care workers' use of Augmented Reality smart glasses affect trusting beliefs of patients?*

Identification (RQ1) and implementation (RQ2) of use cases are important research topics that will help to build artifacts that deliver value to people who provide services to others. However, smart devices are a very conspicuous technology that can be perceived as pervasive by onlookers. Guided by research question three, we aim to derive a deeper understanding of how smart glasses need to be designed and used, such that they will be accepted in their field of application.

1.3 Structure

This thesis consists of three parts. In Part A, we first provide a motivation for the topic, derive research questions, and describe the structure of the thesis (Chapter 1). Then, we provide the conceptual background of this thesis, that is, some background information on Augmented and Virtual Reality, 3D user interfaces, technology acceptance, and trust research (Chapter 2). Next, we describe our research approach for this thesis, which consists of a mixture of design science research, various qualitative methods, as well as experimental designs (Chapter 3). Part B includes six peer-reviewed publications. In the first publication, we provide the foundations for subsequent work by identifying systematic approaches for AR and smart glass use case identification (Chapter 4). Based on that, three publications focus on the implementation of individual use cases (Chapters 5-7). With two further publications, we dive into the challenges of passive trust (Chapters 8 and 9). In part C, we first summarize the results from the publications presented in part B (Chapter 10), discuss our findings (Chapter 11), and provide limitations (Chapter 12), implications (Chapter 13), and topics for future research (Chapter 14). We summarize the structure of the thesis in Figure 1.

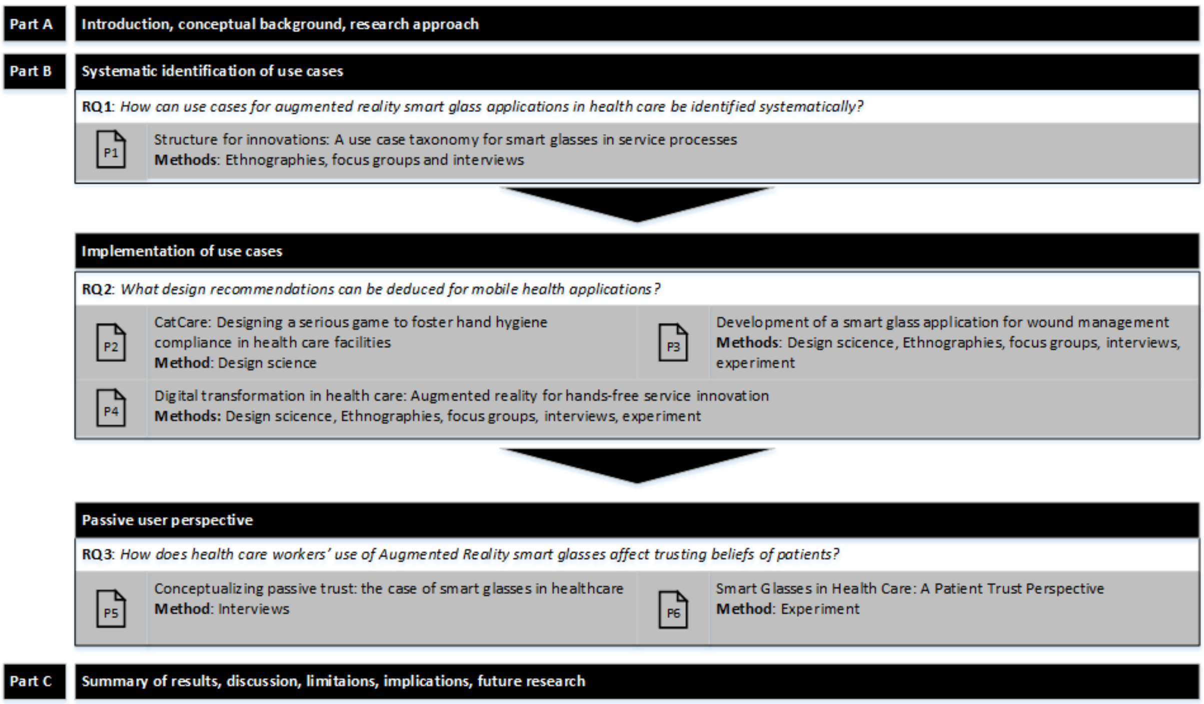

Figure 1: Structure of the Thesis

In the following paragraphs and Table 1, we summarize the six publications that are embedded in part B. For each publication, we briefly outline the research problem, the methodological approach, and the main contributions of each publication (P).

P1: Structure for innovations: A use case taxonomy for smart glasses in service processes (Klinker et al. 2018b). The evolution of smart glasses and AR technology holds potential for support of mobile service processes. Yet, little research has focused on the systematic identification of potential use cases. In this article, we present a use case taxonomy derived from multiple case studies employing literature search, ethnographies, interviews, and focus groups from the domains of nursing, maintenance, and logistics. Building upon the identified use cases, we propose a framework of task-technology fit for smart glasses. The taxonomy, in combination with the framework, will allow researchers and practitioners to identify smart glass use cases that are of inter-domain relevance. Moreover, our artifacts enable a structured approach for identification and assessment of potential smart glass use cases without in-depth knowledge of the technology.

P2: CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities (Klinker et al. 2017). Lack of proper hand hygiene is often the source of hospital-acquired infections. Despite many efforts, on average, health care workers still perform hand hygiene in less than 50% of the occasions in which they must. Serious games have been used successfully to achieve behavioral change in other health care domains. To tackle the complex problem of hand hygiene compliance, we followed a design science research approach combining the build-phase with three evaluation cycles. In this paper, we present a preliminary design of a serious game to explore the possibilities of achieving better hand hygiene compliance of health care workers.

P3: Development of a smart glass application for wound management (Klinker et al. 2019b). Treatment of chronic wounds is a challenging task for health care professionals. When treating chronic wounds, accurate documentation of wound development via photos, measurements, and written descriptions are crucial for monitoring the healing progress over time and choosing the right wound treatment. Currently, however, wound documentation is often perceived as inaccurate and incomplete. In this research, we follow a user-centered design science approach to develop a smart glass-based wound documentation system to support healthcare workers. Through ethnographic fieldwork, interviews, and prototype tests with focus groups, we find that smart glass applications hold potential for improving the wound documentation process because they allow for hands-free documentation at the point of care.

P4: Digital transformation in health care: Augmented reality for hands-free service innovation (Klinker et al. 2019c). Health care professionals regularly require access to information systems throughout their daily work. However, existing smart devices like smartphones and tablets are challenging to use at the point of care because health care professionals require both hands during their work. Following a design science research approach, including ethnographic fieldwork and prototype tests with focus groups, we find that AR smart glass applications offer potential for service innovation in the health care sector. Our smart glass prototype supports health care professionals during wound treatment by allowing them to document procedures hands-free while they perform them. Furthermore, we investigate the use of audio-based and physical interaction with smart glasses in a within-subjects design experiment.

P5: Conceptualizing passive trust: the case of smart glasses in healthcare (Klinker et al. 2019a). In recent years the digitization of healthcare has been moving forward. Emerging technologies, such as smart glasses, are being tested for allowing healthcare workers information access at the point of care while being able to work hands-free. Yet, it remains unclear how the use of smart glasses will affect the trust relationship between patients and caregivers. The patient is not an active user of the smart glasses but is nevertheless dependent on outcomes influenced by the smart glasses. The patient, therefore, becomes a passive trustor of this technology. Building upon existing trust research literature, we present a research model and extend it by interviewing 20 patients about their experiences with caregivers and their perceptions regarding the use of smart glasses in healthcare. We find that communication with patients is a crucial driver of passive trust in technology and trust in caregivers. This research contributes to a better understanding of the trust relationship between patients and caregivers and provides insights into the construct of passive trust in technology. In order to extend the qualitative data analysis, future research should investigate the extent of the acceptance of smart glasses by patients within healthcare facilities.

P6: Smart Glasses in Health Care: A Patient Trust Perspective (Klinker et al. 2020). Digitization in the health care sector is striving forward. Wearable technologies like smart glasses are being evaluated for providing hands-free and septic-safe access to information systems at the point of care. While smart glasses hold the potential to make service processes more efficient and effective, it is unclear whether patients would opt-in to treatments involving smart glasses. Patients are not active users of smart glasses but are nevertheless affected by outcomes produced by the symbiosis of health care workers and smart glasses. Using an online survey with 437 respondents, we find that it is essential to explain to patients why smart glasses are being used and to address data privacy concerns proactively. Otherwise, smart glasses can significantly increase risk perceptions, reduce patients' estimates of health care workers' abilities, and decrease patients' willingness to opt-in to medical procedures.

No.	Authors	Title	Outlet	Type
P1	Klinker, Berkemeier, Zobel, Wüller, Fries, Wiesche, Remmers Thomas, Krcmar	Structure for innovations: A use case taxonomy for smart glasses in service processes	*MKWI 2018 (accepted)*	CON (VHB: D)
P2	Klinker, Wiesche, Krcmar	CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities	*DESRIST 2017 (accepted)*	CON (VHB: C)
P3	Klinker, Wiesche, Krcmar	Development of a smart glass application for wound management	*DESRIST 2019 (accepted)*	CON (VHB: C)
P4	Klinker, Wiesche, Krcmar	Digital transformation in health care: Augmented reality for hands-free service innovation	*ISF 2019 (accepted)*	Journal (VHB: B)
P5	Klinker, Obermaier, Wiesche	Conceptualizing passive trust: the case of smart glasses in healthcare	*ECIS 2019 (accepted)*	CON (VHB: B)
P6	Klinker, Wiesche, Krcmar	Smart Glasses in Health Care: A Patient Trust Perspective	HICSS 2020 *(accepted)*	CON (VHB: C)

Outlet:
MKWI: Multikonferenz Wirtschaftsinformatik
ECIS: European Conference on Information Systems
HICSS: Hawaii International Conference on System Sciences
ISF: Information Systems Frontiers
DESRIST: Conference on Design Science Research in Information Systems

Type:
CON: Conference
VHB: German Academic Association for Business Research

Table 1. Overview on Embedded Publications

2 Conceptual Background

In this section, we describe the theoretical foundations for this thesis. We define the concepts of Augmented Reality technology and elaborate on its connection to technology acceptance and trust literature.

2.1 Augmented and Virtual Reality

Augmented Reality (AR) and Virtual Reality (VR) technologies - collectively often referred to as Mixed Reality (MR) technologies (Milgram/Kishinott 1994), are used to display virtual objects inside the field of view of a user. AR overlaps virtual objects with reality via smart glasses, hand-held devices, or projection systems (Azuma 1997). VR, on the other hand, creates an entirely virtual world in which the user cannot see his real-world surroundings. In contrast, AR technologies allow the simultaneous perception of the real world while seeing virtual objects (Schwald/de Laval 2003). Milgram and Kishino (Milgram/Kishino 1994) classify these different technologies utilizing the so-called mixed reality continuum that ranks AR and VR on a spectrum between the virtual and the real world (see Figure 2 (Azuma 1997; Schwald/de Laval 2003; Milgram/Kishino 1994). The entire spectrum between the real and virtual world is known as Mixed Reality (MR).

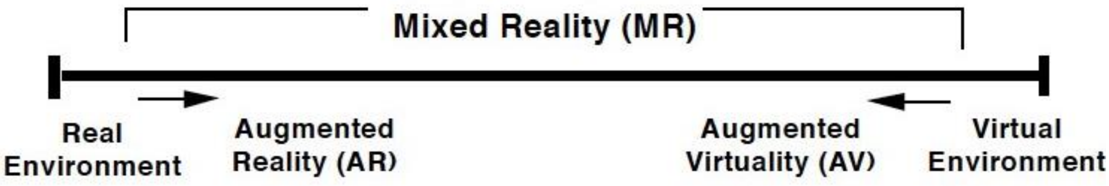

Figure 2: Depiction of the MR-spectrum according to Milgram & Kishino (1994)

MR technologies (Milgram/Kishinott 1994) have the potential to support employees during service provision using immersive means of presenting information (Dini/Dalle Mura 2015). In core sectors such as healthcare and maintenance, AR technologies can be used for services such as wound management or production planning. These services require intensive exchange between the various interest groups such as patients, physicians, customers, engineers, technicians or partner companies. AR can help to visualize products and processes and thereby strengthen the exchange of interest groups.

While VR, as a fully immersive technology, allows users to immerse their senses in a completely virtual world using VR headsets, AR technologies augment virtual content into the real world (Milgram/Kishinott 1994). For VR, there are now a number of providers in the business-to-customer (B2C) area who use VR headsets primarily in the entertainment industry and for communication purposes. Examples include Oculus Rift, HTC Vive, and Microsoft Mixed Reality.

While it is also possible to build VR experiences using caves, VR is typically created using VR headsets. Users of VR headsets immerse themselves in a completely virtual world in which they can no longer see their surroundings. VR headsets are already available from several suppliers on the mass market (e.g., Occulus Rift or the HTC Vive). These products are already relatively mature and cheap in comparison with AR technology. VR headsets have been improving incrementally rather than radically over the last years. VR, however, has inherent limitations due to the complete virtuality of the technology.

On the one hand, movement concepts are challenging to map. Orientation restrictions exist, since cables from the VR headset have to be attached to a nearby PC. On the other hand, there are translation restrictions, since the use of VR headsets is only intended for a fixed area (typically about 2x2 meters). Furthermore, VR headsets are often connected via cables to a nearby PC. This is done to outsource most of the processing to the PC, as highly immersive VR experiences often require a lot of computing power. VR is, therefore, not suitable for mobile contexts, which makes them a bad fit for mobile service processes.

From a historical perspective, a large number of potential use cases were already envisioned at the very beginning of the development of AR technologies during the 1990s. These range from applications in medicine to robotics to the entertainment industry (Azuma 1997). At the same time, however, a large number of technical challenges prevailed that limited the applicability of AR solutions in real-world scenarios. For instance, the hardware prototypes used in the entertainment industry were too bulky and too expensive for widespread adaptation. It wasn't until about 2004 that progress in the field accelerated considerably due to advances in mobile computing and hand-held AR. For instance, Mohring, Lessig, and Bimber were among the first to develop AR applications for smartphones (Mohring et al. 2004).

As technical limitations were identified as the main hindrance to AR adoption, the AR scientific community at the time mainly focused on topics such as tracking (using various methods for identifying the relevant objects in the real world that are to be augmented) and interaction with virtual objects (e.g., gesture control, collaborative AR applications) (Zhou et al. 2008). Over the last decade, however, a large number of tools and environments for the development of AR applications have emerged, each of which supports different applications of AR and phases of AR implementation (Wang et al. 2013), such as ARToolkit, Vuforia or EasyAR.

Due to technical challenges with spatial consistency between the real and virtual world, AR displays are less widespread than VR headsets. However, several technical barriers have been overcome in recent years, which is why sophisticated AR glasses are now increasingly appearing on the market, e.g., Microsoft HoloLens and Magic Leap. In contrast to VR, users of AR technologies can see their surroundings while being able also to see virtual objects. The virtual objects are embedded in the real world for the user and can display additional information. Consequently, AR can also be used well in mobile contexts. Yet, tracking technology is still a limiting factor that makes it challenging to use AR technologies in practice. Tracking is required to recognize distinctive points in the user's surroundings in real-time. This is needed to calculate where the virtual objects have to be displayed on the smart glass screens such that the user gets the impression that the virtual objects are rigidly located in the real world.

With the progression of AR technology and software frameworks, the locus of research attention has shifted from technological aspects to the applicability of AR in real-world use cases. The digitization of production-related service processes through AR/VR technologies requires not only a high degree of creativity but also technological expertise (Dietrich/Schirra 2006). There are three effective approaches to implement AR on end devices. In practice, this is mainly done using smart glasses (also called head-mounted displays), projectors, or hand-held devices such as smartphones or tablets (Billinghurst et al. 2001). Figure 3 illustrates these three ways of inserting virtual objects in the user's field of vision. Also, AR applications can be distinguished as optical see-through (OST) or video see-through (VST) devices (Rolland/Fuchs 2000). When using a VST device, the user sees the real world through a device with a live video stream that is augmented by virtual elements. OST devices do not make use of live streaming. Instead, they use means such as semi-transparent lenses to insert virtual objects directly into the user's line of sight.

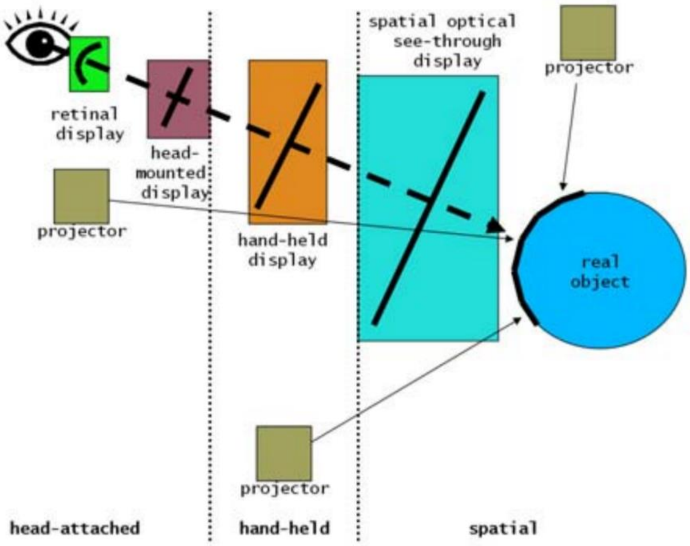

Figure 3: Technical approaches to augment virtual objects into the line of sight of the user. Figure adapted from (Bimber/Raskar 2006)

2.1.1 Hand-held augmented reality

Hand-held AR is mostly based on devices such as smartphones and tablets using VST-AR. A prominent example of this is the AR game Pokemon Go (Howe et al. 2016), which had more than 30 million active users in 2016. Many further AR apps can be found on the iOS and Android app markets. However, hand-held devices have inherent limitations. First, smartphones and tablets have to be held in one hand, depriving users of the option to use both hands for other tasks. Furthermore, smartphones only fill a small part of the field of vision of their users, making it difficult for them to locate all virtual objects in their surroundings.

Many hand-held AR applications make use of marker-based tracking frameworks (e.g., ARToolKit, Vuforia, etc.). Recently, Apple has come forward with an AR framework called ARKit, which works without marker tracking, an approach referred to as markerless tracking (Simon et al. 2000). Markerless tracking makes it possible to calculate the position and orientation of a hand-held device relative to its surroundings without relying on visual markers that have to be placed in the real world. This has the advantage that the user hardly needs any technical knowledge. It is only required that the user starts an app on his hand-held device and can then start using AR features immediately. It is conceivable that this markerless technology would also be suitable for supporting service processes. Future research is needed to identify potential use cases.

2.1.2 Augmented reality smart glasses

Augmented Reality smart glasses are typically built using OST hardware setups. This allows adding virtual objects directly into the user's view of the real world, e.g., via beam splitter or semi-transparent AR lenses. Displays and tracking systems are often built directly into the smart glasses, which makes it possible to display and manipulate virtual objects in the user's field of view (Evans et al. 2017). AR smart glasses are also often referred to as head-worn AR (Bimber/Raskar 2006).

The pace of innovations for AR smart glasses has increased considerably in recent years. With the HoloLens, Microsoft has launched a product that is cheaper than many other smart glasses with AR capabilities, has excellent battery performance, and impressive markerless tracking capabilities. One can assume that technological leaps of AR smart glasses in the coming years are likely. The technology is expected to become better regarding its field of view, tracking and on-board computing power while becoming more affordable. This makes it imaginable that it could become cost-effective to use them for supporting service processes.

Research in the AR smart glasses area has so far been limited primarily to technical details and user tests in laboratory settings. Due to AR's technological leaps in the near past, research focused on testing the technology in practice is shifting into researchers' attention. Therefore, within this dissertation, we have focused our efforts on conditions in which this technology can offer added value for small and medium-sized companies in their service processes.

2.2 3D user interfaces

According to Bowman et al. (Bowman et al. 2004), three-dimensional (3D) user interfaces are defined by the fact that the VR / AR interactions are carried out directly in a real or virtual spatial 3D context. It is crucial that not only conventional elements of the 2D user interface are used to change the 3D output, but actions are used directly in 3D space (Bowman et al. 2004). However, the interactions used do not have to be exclusively in the 3D context, but can also include combinations of 2D and 3D interactions.

An essential term in this context are the degrees of freedom (DoF) provided by the user interface. The DoF refer to the number of independent dimensions of the possible movement of an object in three-dimensional space. For example, the movements of a computer mouse can be tracked in two orthogonal directions on a two-dimensional surface, resulting in two DoF. VR / AR input devices such as the HTC Vive Controller, on the other hand, can record both shifts and rotations along the three spatial axes and thus allow 6 DoF. In addition, virtual objects can often also be scaled along the three spatial axes, that is to say, modified in size, which means that an additional 3 DoF are available.

Based on the work of Bowman and Hodges (Bowman/Hodges 1997), LaViola et al. 3D interactions for such environments are divided into the following categories (LaViola 2017):

- **Selection and manipulation**: It must first be specified which object the user would like to interact with to carry out further object manipulations (e.g., changing the position, orientation, and size of elements of a production system) (Frank Steinicke 2006).

- **Navigation**: Navigation through a VR / AR environment can be done according to Bowman et al. (1997) in two ways: (i) moving through virtual objects or surroundings by manipulating the camera position and orientation, and (ii) via path finding, which describes the cognitive part of the navigation through which paths are planned or desired views of individual components are identified.
- **System control**: In addition to selection, manipulation, and navigation, the system status must be changed in many applications, e.g., change in material properties or meta-information (LaViola 2017). Such tasks can typically be accomplished through selection and manipulation using 3D menus. The symbolic entry of numbers and letters also falls into this category.

2.3 Technology acceptance

Many models and theories for technology acceptance are adaptations of models from sociology and psychology. Many technology acceptance models have been tested extensively over the last decades (Venkatesh et al. 2003). The most cited ones are the Technology Acceptance Model (TAM) (Davis, Bagozzi, and Warshaw 1989), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003) and UTAUT2 (Venkatesh, Thong, and Xu 2012).

All of these models are adaptations of the theory of planned behavior (TPB) (Ajzen 1991). TPB was developed by Icek Aijzen and is used to explain why individuals engage in certain behaviors. A graphical representation of TPB is depicted in Figure 4. TPB posits that the constructs "attitude towards a behavior", "subjective norm", and "perceived behavioral control" predict an individual's intention to engage in a specific behavior. The intention to engage in a certain behavior, in turn, predicts the actual behavior of the individual quite well. TPB has been used in a plethora of application fields. It has been used to predict health-related behaviors (Godin/Kok 1996), leisure choices (Ajzen/Driver 1992), hunting intentions (Hrubes et al. 2001), compliance with speed limits (Elliott et al. 2003), alcohol use and misuse (Marcoux/Shope 1997) as well as entrepreneurial intent (Shook/Bratianu 2010).

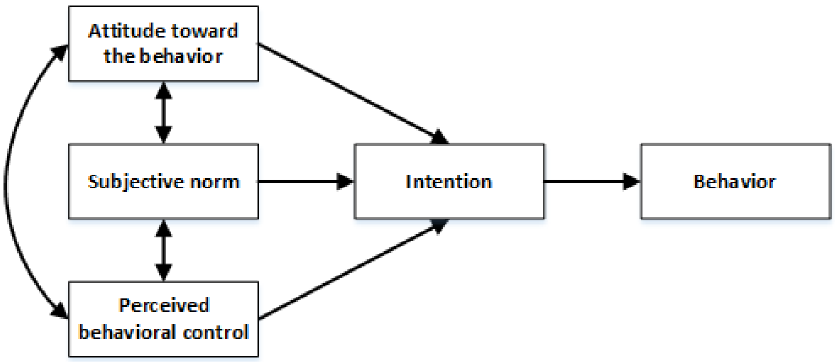

Figure 4: Theory of Planned Behavior (adapted from (Ajzen 1991))

Fred Davis developed TAM during his PhD thesis (Davis 1985). The constructs of TPB were adapted from a broader context to make predictions about individual's technology adoption behaviors. TAM uses the constructs of perceived ease of use (PEOU) and perceived usefulness (PU) to predict behavioral intention (BI) to use a technology and then measure actual use (AU) of it. After its initial proposition in 1985, TAM has been applied in many contexts, such as telemedicine (Hu et al. 1999), e-commerce (Pavlou 2003), wireless internet (Lu et al. 2003), online banking (Pikkarainen et al. 2004) or e-learning (Park 2009). TAM has been adapted to many contexts, and extended models (TAM2 (Venkatesh/Davis 2000) and TAM3 (Venkatesh/Bala 2008)) also exist.

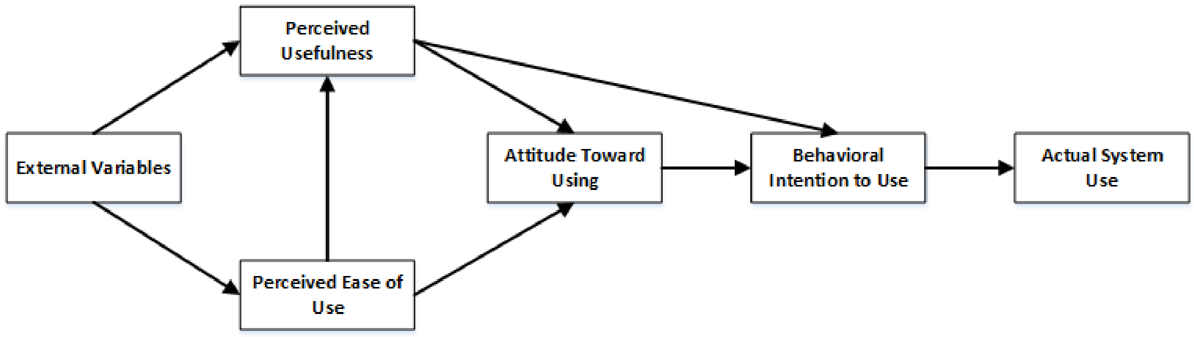

Figure 5: Technology Acceptance Model (adapted from (Davis 1989))

Furthermore, within technology acceptance research, the unified theory of technology acceptance (UTAUT) and its augmentation (UTAUT2) are very renowned technology acceptance models. Venkatesh et al. developed UTAUT in 2003 (Venkatesh et al. 2003) to unify a plethora of existing technology acceptance frameworks into one generalized model. Figure 6 shows a visual representation of the UTAUT model. UTAUT differs from TAM in that the constructs of social influence (SI), facilitating conditions (FC), and the moderating variables of gender, age, experience, and voluntariness of use were added. Moreover, the PEOU and PU constructs of TAM were slightly changed to the effort expectancy (EE), and performance expectancy (PE) constructs in UTAUT (Venkatesh et al. 2003). The UTAUT model has been applied in many contexts such as student's acceptance of course management software (Marchewka/Kostiwa 2007), mobile banking (Yu 2012), e-government (AlAwadhi/Morris 2008), automated road transport systems (Madigan et al. 2016) or use of mobile smart devices (El-Gayar/Moran 2006).

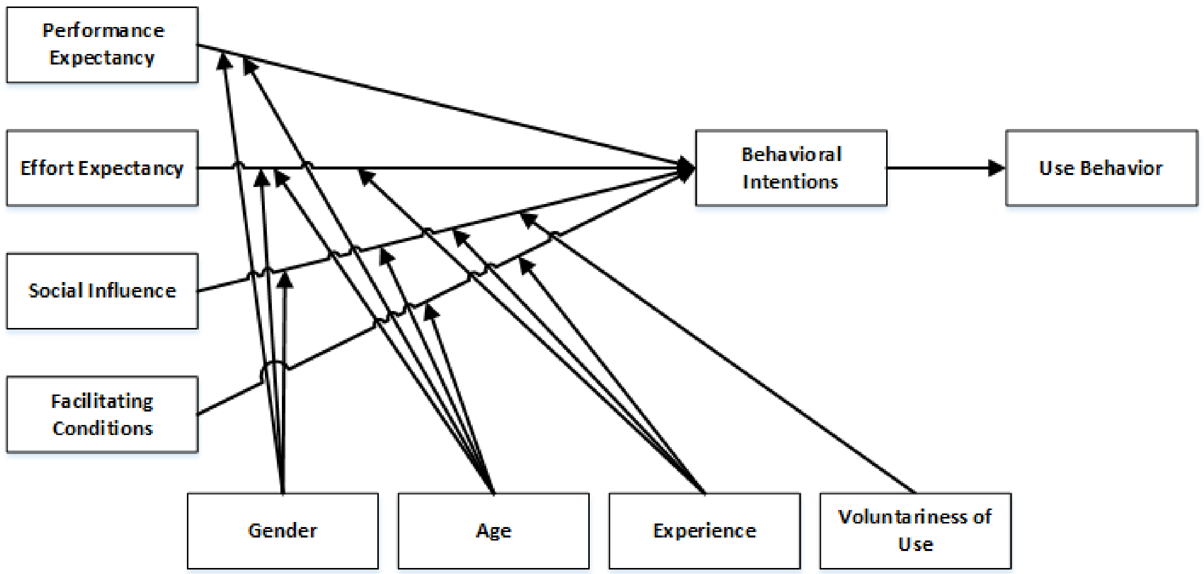

Figure 6: Unified Theory of Technology Acceptance (adapted from (Venkatesh et al. 2003))

UTAUT was developed with involuntary use settings in mind. To tailor UTAUT to consumer settings, UTAUT2 was developed (Venkatesh et al. 2012). The UTAUT2 model is depicted in Figure 7 UTAUT2 augments UTAUT by adding the constructs of hedonic motivation (HM), price value (PV), and habit (H). UTAUT2 has also been used in many contexts such as mobile banking (Raman/Don 2013; Alalwan et al. 2017; Arenas Gaitán et al. 2015), NFC payments (Morosan/DeFranco 2016), mobile learning (Yang 2013), fitness apps (Yuan et al. 2015), social recommender systems (Oechslein et al. 2014), online games (Xu 2014) and wearable devices (Son et al. 2014).

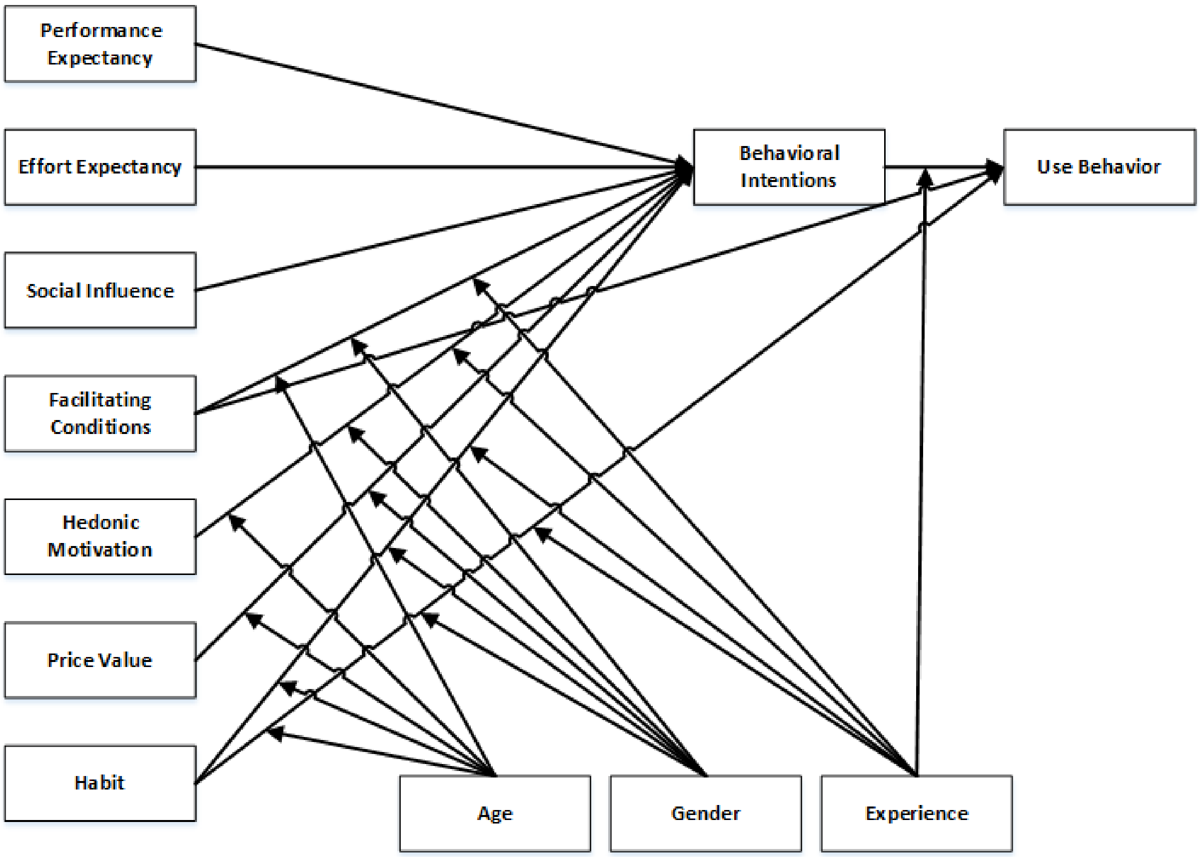

Figure 7: Unified Theory of Technology Acceptance 2 (adapted from (Venkatesh et al. 2013))

2.4 Trust research

Trust research in the field of Information Systems started in the late 1990s (Söllner et al. 2016). Different definitions of trust exist. In this dissertation, we use the definition of trust by Mayer et al. (1995):

> *"Trust is the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party."* (Mayer et al. 1995)

Trust is, therefore, a decision to make yourself vulnerable and to depend on another party. This decision is based on the basic willingness of the trust-giver to trust others and on his assessment of various characteristics of the trust-taker (Mayer et al. 1995). It is important to mention that trust is always context-dependent. This means that the decision to trust a particular entity can differ depending on the situation. For example, one might trust a cook to prepare a dish correctly, but less so when it comes to building a house.

Definitions derived from the management discipline, such as those of Mayer et al. (1995), are often used in IS research (Söllner et al. 2012). The definition refers to trust between different people, groups, or organizations. Thus, it is also suitable for the investigation of technology-supported relationships such as those used in online trading (Gefen et al. 2003; McKnight/Chervany 2001), in the virtual world of work (Hill et al. 2009) or virtual communities (Leimeister et al. 2005). In the following, we will take a deeper look into two subdisciplines of trust that are of particular interest to this dissertation project.

2.4.1 Trust in person

Research on interpersonal trust within the IS community started with the model developed by Mayer et al. (Mayer et al. 1995). A depiction of their model can be seen in Figure 8. Trusting relationships always include two entities: A trustee who is the trust-taker and a trustor, which is the person or organization who has to decide whether or not to put faith in the trustee (Söllner et al. 2012).

According to Mayer et al. (1995), perceived trustworthiness directly influences a trustor's trust in the trustee. The dimensions of ability, benevolence, and integrity are the main factors that influence perceived trustworthiness. Benevolence is defined as the perception of the trustor that the trustee not only follows an egocentric profit motive but also wants to do good to the trustor. The dimension of integrity reflects the trustor's view that the trustee adheres to certain principles that he accepts (Mayer et al. 1995). Ability reflects the trustor's impressions on whether the trustee has the ability or competence to fulfill the trustor's expectations. Furthermore, the propensity to trust varies among trustors. The propensity to trust has a moderating influence on the relationships between ability, benevolence, and integrity on the trustor's trusting beliefs. Moreover, the perceived risk of trusting the trustee has a moderating influence on actual risk taking behavior of the trustor.

The research model of Mayer et al. has been used in many IS research contexts such as learning behavior in work teams (Rousseau et al. 1998), e-commerce (McKnight et al. 2002), ethical leadership (Brown et al. 2005), communication in global virtual teams (Jarvenpaa/Leidner 1999), knowledge transfer (Levin/Cross 2004) and virtual communities (Chiu et al. 2006).

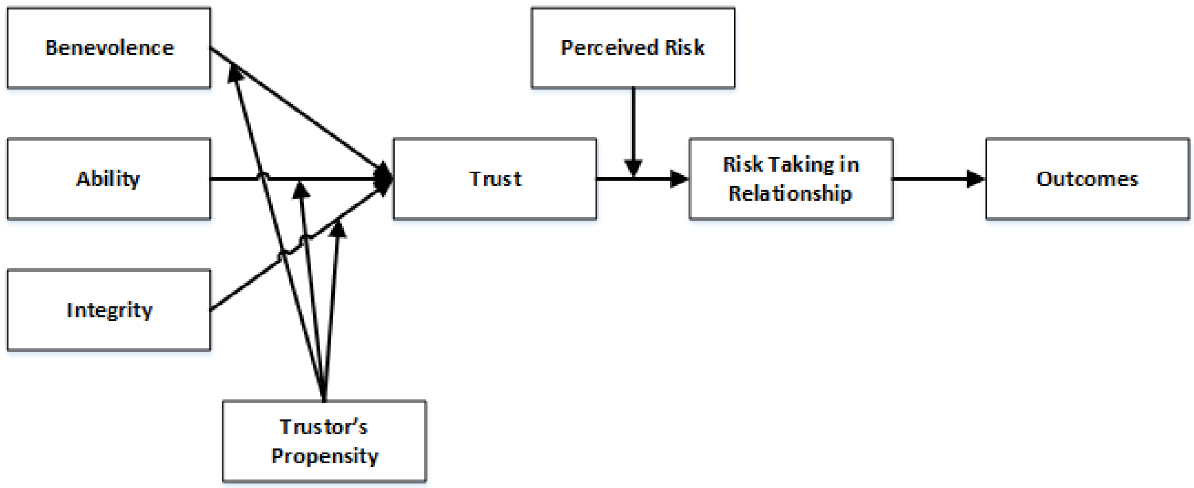

Figure 8: Model of Trust (adapted from (Mayer et al. 1995))

While the model of Mayer et al. is well known in the IS trust literature, other conceptualizations of trust exist. For instance, McKnight et al. (2001) use a predictability construct, which relates to the consistency of the actions of a trustee. According to Fulmer (2012), communication between the trustor and the trustee plays a vital role in the development of interpersonal trust. Also, different types of communication were found to influence trust in a person. For example, face-to-face communication enables greater trust than online communication via video chats or text chats (Robert et al. 2009; Inbar/Tractinsky 2010). This effect is weakened over time by collecting additional trust information regarding the other party (Hill et al. 2009). Furthermore, Riedl et al. (2014) describe the degree of naturalness of a communication medium and its effect on trust in people. They find that a low level of naturalness of a trustee can affect the trustor's satisfaction, performance, and productivity in various collaborative tasks Riedl et al. (2014).

In trust research, a distinction is also made between initial trust formation and knowledge-based trust formation. Initial trust is by definition not based on experience gained throughout interactions with another party, but on an individual's disposition to trust or on institutional cues that enable one person to trust another without firsthand knowledge (McKnight et al. 1998). This means that the trustor develops initial beliefs about the trustworthiness of the other party based on factors related to the situation and the trustee himself, but not based on the trustee's behavior (Jarvenpaa et al. 2004). The development of trust is viewed as an attribution process (Jarvenpaa et al. 2004). Attribution theory (Kelley 1967) describes social perceptions that arise when people try to explain a person's past or future actions. Knowledge-based trust is built as soon as enough information is available to assess a trustee's trustworthiness. This kind of trust results from the perceived abilities, integrity, and benevolence of the other person (Robert et al. 2009).

2.4.2 Trust in technology

Research into user's trust in technology is expected to require different research approaches than interpersonal trust (Söllner et al. 2016). Yet, many conceptualizations within the trust in technology research share similarities with interpersonal trust models. For instance, the research of Mcknight et al. (2011) derives a nomological net for trust in technology by translating constructs from interpersonal trust literature. The authors argue that the dimensions of ability, integrity, and benevolence can be transferred into the technological context. The ability construct of interpersonal trust is thereby mapped to whether a technology has the functionality that is necessary to accomplish given tasks. Users estimate the extent to which a technology has certain functions to fulfill a specific task. Integrity reflects the extent to which trustors act consistently, reliably, and according to accepted principles. In the technological context, integrity maps to the reliability of a technology. The user thus assesses whether the technological trustee acts consistently over all its functionality. Despite the lack of free will of a technology, it can be faulty. Technology follows specific algorithms or logic. McKnight et al. (2011) argue that the interpersonal trust construct benevolence can be transferred to helpfulness in the technological context. The authors acknowledge that users will not sense caring emotions, because technology itself has no moral agency. Other authors have also pointed out the difficulties that arise when transferring the concept of benevolence into the technological context since no adequate comparison can be made with human decision-making (Söllner et al. 2011). However, McKnight et al. argue that users do hope that a technology's help function will provide the advice necessary to complete a task. Despite the lack of moral authority, users thus evaluate how appropriate, effective, and fast the built-in help functions of a technology provides useful advice.

2.4.3 Active and passive trust in technology

Trust in technology research within the IS domain has been focused on an active user perspective. The active user is the person who is controlling and interacting with the trustee technology. On the other hand, passive users are people who are not in direct control of the technology but who are affected by outcomes that are produced by an active user's use of technology (Lee et al. 2015). The willingness of passive users to trust is referred to as "passive trust". Research on passive trust in technology is an emerging research topic with some unique characteristics. First of all, passive trust encompasses two trustees: The active user and the technology the active user is using. It is thus likely that the passive user's perceptions about the technology and the active user will both have an influence on passive trust. Second, as the passive user does not directly control or interact with the technology, she has limited perceptions about the technology. Future research is thus required to identify which factors, known from the active trust in technology research context, are transferable to the passive context. Furthermore, it is quite possible that additional factors exist for the passive context.

A lot of conceptual work on passive trust has been done in the field of ergonomics by the research group of Enid Montague. They define a passive user as an individual who has only limited control over the technologies and IT artifacts used in a system but is nevertheless directly affected by the results and the outcome of the technology use (Montague/Xu 2012). They further describe that a passive user can observe and assess the actions and interactions of the active user with the technology and can use these perceptions to estimate the functionality and reliability of a technology. Moreover, they found that trust in technology within the medical field is different from trust in technology in other areas (Montague et al. 2009). In the medical context, patients represent passive users of medical technologies, while doctors and nurses act as active users.

3 Research Approach

To investigate opportunities for Augmented Reality in the domain of health care, this dissertation project combined predominantly qualitative exploratory research methods such as ethnographies, focus groups and interviews (P1). In the next step, a combination design science research approaches with quantitative and qualitative evaluation methods were used to design and evaluate artifacts that tackle individual IS uses cases in the health care domain (P2-P4). Quantitative and qualitative research methods such as experiments, focus groups, interviews, and ethnographies were used to explore the problem space and to evaluate the developed artifacts. Finally, a combination of interviews and surveys-based experiments was used to create a nomological net of passive trust and to validate models from interpersonal trust and active trust in technology research (P5, P6). Table 2 gives a more detailed overview of the methods that were employed in the individual publications of this dissertation project.

Publication	Experiment	Ethnographies	Focus groups	Interviews	Design Science
Structure for innovations: A use case taxonomy for smart glasses in service processes (P1)		X	X	X	
CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities (P2)				X	X
Development of a smart glass application for wound management (P3)	X	X	X	X	X
Digital transformation in health care: Augmented reality for hands-free service innovation (P4)	X	X	X	X	X
Conceptualizing passive trust: the case of smart glasses in healthcare (P5)				X	
Smart Glasses in Health Care: A Patient Trust Perspective (P6)	X				

Table 2. Overview of Research Methods Applied in the Embedded Publications

The following sections provide more in-depth descriptions of the individual research methods employed throughout this thesis.

3.1 Design Science Research

Design science research (DSR) has its roots in engineering and the sciences of the artificial (Herbert 1996). It has been an important paradigm of IS research since the inception of the field, and its general acceptance to IS research is increasing (Hevner/Chatterjee 2010). Design science creates and evaluates IT artifacts intended to solve identified organizational problems (Hevner et al. 2004). DSR projects contribute to theory by generating two types of knowledge: Descriptive and prescriptive knowledge (Gregor/Hevner 2013). Descriptive knowledge is the “what“-knowledge about natural phenomena and the laws and regularities among phenomena, while prescriptive knowledge explains the “how” of human-built artifacts (Gregor/Hevner 2013).

DSR has been conducted in many research contexts, such as decision support systems (Arnott 2006), collaboration processes (Kolfschoten/De Vreede 2009), technology forecasting (Adomavicius et al. 2008), culturally adaptive interfaces (Reinecke/Bernstein 2013) or agile requirements engineering (Adikari et al. 2009).

Over time several methods for conducting design science research have been developed (Hevner 2007; Peffers et al. 2007; Sonnenberg/Vom Brocke 2012). One of the most renowned conceptualizations of DSR is the framework proposed by Hevner et al. (2004). Figure 9 shows a visual depiction of it. The framework proposes a distinction between relevance, rigor and design cycles, which are used to conduct design science research. The rigor cycle is used to derive insights from the scientific literature and to enable researchers to apply them in the research context. The relevance cycles help to ensure relevance of the DSR project by grounding it in a practical setting. Employing qualitative or quantitative research approaches, researchers identify business needs in a specific business domain. Building on insights from science and practice DSR projects then proceed to build and evaluate artifacts in design cycles iteratively.

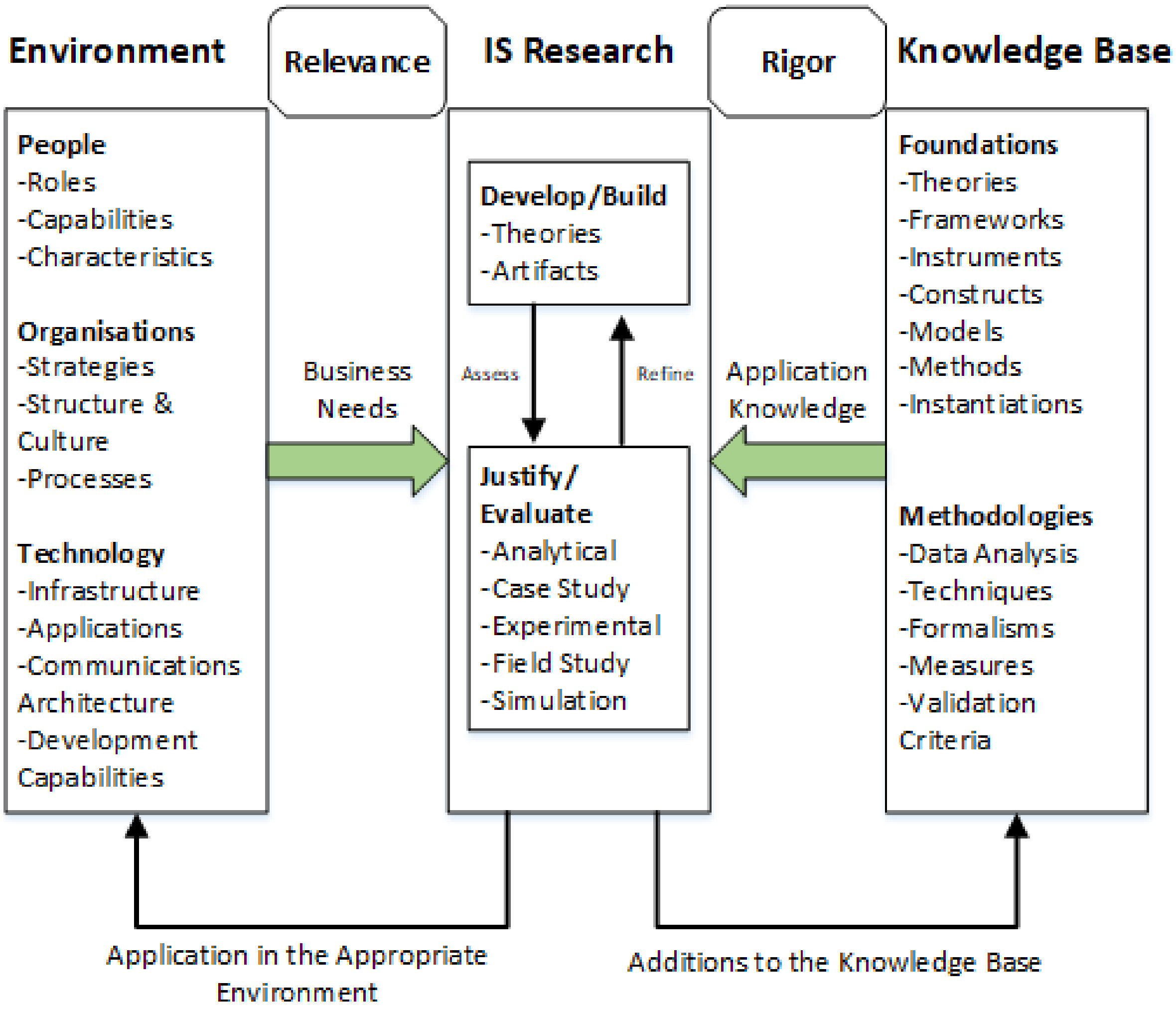

Figure 9: Information Systems Research Framework of (Hevner et al. 2004)

Many aspects of the Hevner's framework can be found in DSR methods. One well-cited method is the method of Peffers et al., which the authors named the Design Science Research Method (DSRM)(Peffers et al. 2007). The DSRM is depicted in Figure 10. It applies Hevner's framework in that it emphasizes iterative design and evaluation cycles. Furthermore, similar to Hevner's relevance cycle, the DSRM encourages researchers to identify their problems in practical settings. DSRM provides value by putting individual phases into a logical order.

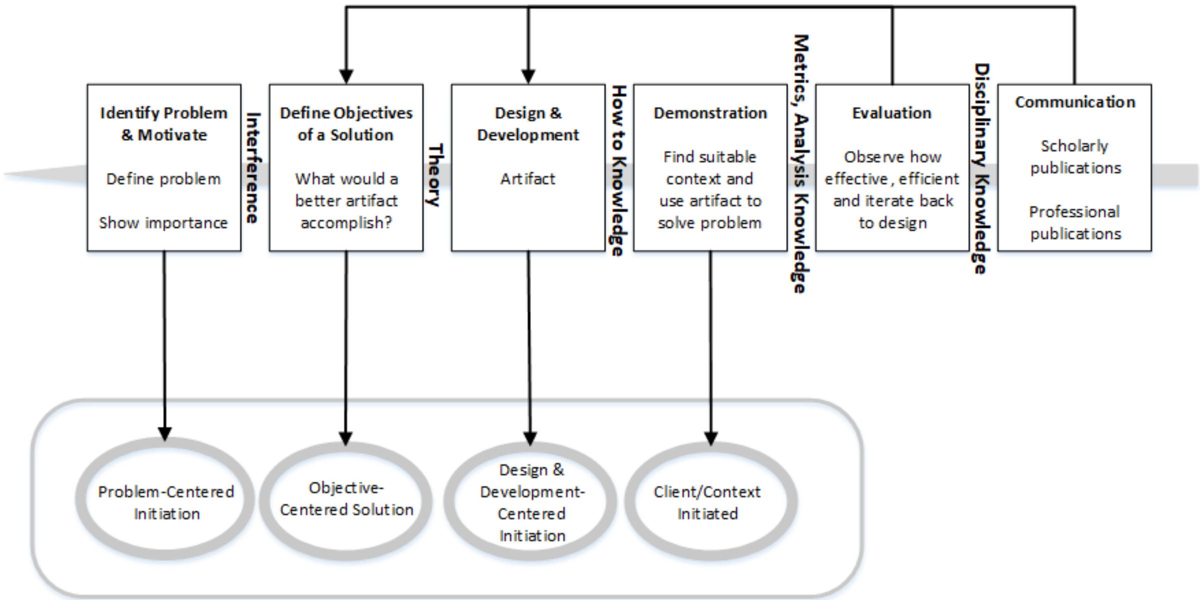

Figure 10: Design science research method of (Peffers et al. 2007)

3.2 Interviews

Three types of interviews exist: Structured, unstructured, and semi-structured (Longhurst 2003). While structured interviews follow a predetermined and standardized set of questions, semi-structured and unstructured interviews are more open and allow each interview to develop an individual dynamic. These interview types can be seen as broad categories on a continuum (Qu/Dumay 2011).

Figure 11 shows a depiction of the interviewing continuum. In this dissertation project, we mainly used semi-structured interview techniques as an exploratory approach to gain in-depth insights into phenomena in the early stages of research projects. In most cases, we used semi-structured interview guides combined with specific interview techniques, which we will outline in the following.

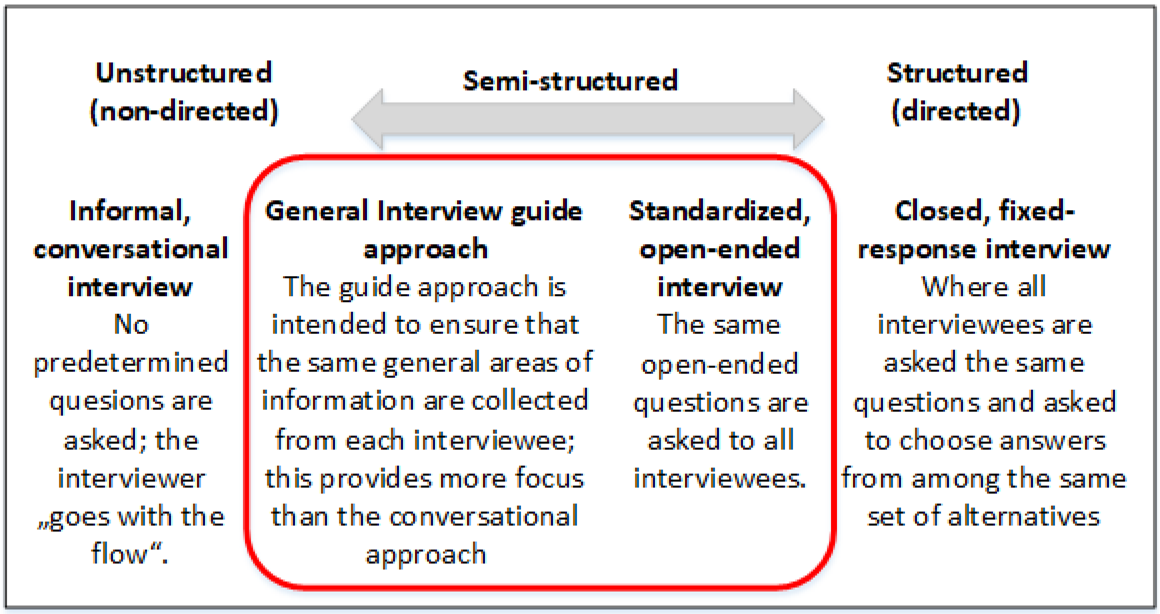

Figure 11: Continuum of unstructured, semi-structured and structured interviews (adapted from (Raziskovanja/Naravovarstva 2011)). This disseration project employed semi-structured interview approaches which are indicated by the red shape.

3.2.1 Critical incidents technique

Flanagan published the Critical Incident Technique (CIT) after he used it in World War II to determine the suitability of soldiers for the U.S. Air Force (Flanagan 1954). Since then, CIT has developed into a widely used qualitative research method and is now recognized as an effective tool for situation analysis (Butterfield et al. 2005). CIT mainly describes a process for collecting essential factors that influence the behavior of certain people in defined key situations (Flanagan 1954). The causes, contextual conditions, and effects of past critical situations and actions are recorded to show and analyze relationships and to derive new knowledge (Flanagan 1954). According to Flanagan, CIT is not about a collection of rigid rules but about flexible principles that have to be modified and adapted to the specific research context.

The critical incidents method is carried out in five steps (Flanagan 1954). In the first step, the aim of the study and the underlying research question should be defined. The second step of the method is to determine the types of events to be collected. The data acquisition in the third step can be carried out using various methods. Direct observations can be used to study explicit behavior, while open questionnaires are useful for capturing cognitive activities and emotions. To increase the quality of the information received, the interviewer must provide the interviewee with specific questions to provide help in the accurate description of the situation (Flanagan 1954). The evaluation and analysis of the collected data describe the fourth step of the CIT. Flanagan (Flanagan 1954). The goal of this phase is to efficiently summarize and describe the data so that it is suitable for use in many practical scenarios (Flanagan 1954). The fifth and last step is to interpret the results of the study, to discuss them, and to disseminate them tailored to the target group (Flanagan 1954).

Within the field of Information Systems, the critical incidence technique has mostly been used in reduced forms and has generally been underutilized (Gogan et al. 2014). In this dissertation project, the critical incident technique was used as an exploratory research method that helped to identify factors that positively or negatively influenced patients' trust in health care professionals and medical technology (P5). Appendix A shows the interview guide that was used in the study. Interview participants were asked to remember critical incidents that had a lasting impact on their trust in the health care system. The aggregates of critical incidents over several interviews helped us to verify factors mentioned in the trust literature but also to identify new factors that we then tested using an online survey (P6).

3.2.2 Think-aloud

Think aloud is another interview technique that was used in this dissertation project on several occasions. It is especially useful for the knowledge acquisition in the context of building knowledge-based computer-systems (Van Someren et al. 1994). Jacob Nielsen describes the think-aloud method as follows: "Simple usability tests where users think out loud are cheap, robust, flexible, and easy to learn. Thinking aloud should be the first tool in your UX toolbox, even though it entails some risks and doesn't solve all problems" (Nielsen 1993).

Conducting a think-aloud evaluation of an IT-artifact is rather easy compared to other research methods. Nielsen breaks the research method down rather bluntly into the following three steps (Nielsen 1993):

1. Recruit representative users
2. Give them representative tasks to perform
3. Listen and let the users do the talking

While this high-level description of the process seems rather straightforward, one should be aware that some experience is still required. Especially if the user gets stuck during a task and clarifications are needed. Table 3 goes more into detail on the strengths of the think-aloud research method, and Table 4 gives an overview of potential challenges when applying it. Appendix B shows a semi-structured interview guide we used in P2.

Strengths	Description
Cheap	No additional equipment needed – just taking notes or recording the interview. Very often, it is helpful to film the user's interaction with a prototype to be able to go back and analyze individual aspects of interactions with the prototype between different users.
Robust/rigorous	Opportunities for biasing participants present themselves to a much lesser extent than with other qualitative research methods (e.g., interviews or focus groups), because the main idea of the method is that the experiment supervisor remains silent. To assert robustness, it is essential that the tasks are explained clearly before the session starts, and a strategy is in place that determines how the experiment supervisor deals with clarifying questions that are sometimes asked by the participant. Furthermore, one benefit of the method is that the analysis of the results can be done in a very transparent manner.
Flexible	Think aloud can be used in all stages of design science projects to evaluate artifacts.
Convincing	Seeing with your own eyes how the user interacts with the artifact you have developed is eye-opening. False assumptions that (implicitly) went

	into the artifact design become apparent throughout think-aloud sessions. After having put a lot of effort and thought into the artifact and receiving evaluation results that imply design flaws can lead to defensive behavior. The first impulse is often to question the robustness of the evaluation results. As think-aloud is a very robust and transparent research method, it is easier to accept the results and to move on to redesign activities.
Easy to learn	When compared to other research methods (e.g., interviewing, experiments) it only takes very little time and effort to learn how to conduct a think-aloud evaluation. Many other research methods have a steep learning curve and require months or years of focused dedication to become an expert. In the case of think-aloud, it is rather a matter of days.

Table 3: Strengths of the think aloud research method. Categories & descriptions based on (Nielsen 1993) and modified by the author.

Challenges	Description
Unnatural situation	For participants who are not experience with the method it often feels unnatural to talk in a monologue of whatever comes to their mind during an evaluation. It is often advisable to do a few practice rounds with the method and to show demonstration videos of think-aloud sessions.
Filtered statements	Participants often experience evaluation apprehension during testing. Some want to appear smart and will not voice uncertainties or doubts. The best solution for this is to train the method properly before the actual evaluation is conducted and to get the participant into the mindset that the intuitiveness of the artifact design is what's being tested and not the intelligence of the user. In case the user stops to voice his thoughts during the actual session, it is possible to give a reminder to voice thoughts as they come. However, one should keep in mind that this is a potential source of introducing bias.
Biasing user behavior	Prompts and clarifying questions sometimes become necessary, but can easily influence user behavior. The researcher should be wary of this and exclude individual sessions if the researcher has reason to believe that bias was introduced.
No panacea	While flexibility to a wide variety is a strength of this research method, it is a good idea also to use other methods to triangulate findings. This is especially true for later stages of design science projects. Here, the focus of the research often switches from exploration to validation. During validation, it is advisable to use quantitative research methods to get robust insights from large sample sizes and to use think-aloud then to make sense out of the aggregated data.

Table 4: Challenges of the think aloud research method. Categories & descriptions based on (Nielsen 1993). Descriptions changed by the author.

3.3 Focus groups

The use of focus group methods to evaluate and refine design artifacts is relatively new to the IS field (Tremblay et al. 2010). A focus group is defined as a moderated group discussion among six to twelve people who discuss a topic under the direction of a moderator whose role is to promote interaction and keep the debate on the subject of interest (Stewart et al. 2007). Tremblay et al. further distinguish between exploratory focus groups (EFGs) and confirmatory focus groups (CFGs) for the use of focus groups in design science projects (Tremblay et al.

2010). EFGs, are used for the design and refinement of an artifact, while CFGs are used for the confirmatory proof of an artifact's utility in the field (Tremblay et al. 2010). Table 5 provides an overview of the key reasons for applying focus group research in design science projects.

Key reasons	Description
Flexibility	Focus groups allow for an open format and are flexible enough to handle a wide range of design topics and domains
Direct Interaction with Respondents	The researcher is put into direct contact with domain experts and potential users of the design artifact. This allows the researcher to clarify any questions about the design artifact as well as probing the respondents on certain key design issues.
Large Amounts of Rich Data	The focus group interactions produce a large amount of information in the form of qualitative and quantitative feedback. This rich data set allows deeper understandings, not only on the respondents' reactions and use of the artifact but also on other issues that may be present in a business environment that would impact the design.
Building on Other Respondent's comments	The group setting, with its opportunities for interactions, allows for the emergence of ideas or opinions that are not usually uncovered in individual interviews.

Table 5: Key reasons for applying focus group research in design science projects put forward by (Tremblay et al. 2010).

Within this dissertation project, focus group research was used in several research projects (P1, P3 and P4). EFGs were mainly used at the beginning of projects to gain insights into current processes in health care facilities and to discuss with experts how processes could be improved using Augmented Reality or mobile Health applications. CFGs were often used at intermittent stages of design science projects. We would meet with a group of health care experts and let them test one or several artifacts. The group discussions after the evaluations were very helpful to clarify which parts of the artifact design would be helpful in service delivery and where the potentials for improvements lie.

3.4 Ethnographies

Ethnography, as one of the oldest social science research approaches, was originally developed in anthropology (Dixon-Woods 2003). Dixon-Woods (2003) describes the method of ethnography as a holistic approach, which makes use of various methods of data collection to describe and analyze everyday situations and routines in their natural surroundings. Methods of data collection range from unstructured observation to targeted investigation and the questioning of selected situations (Dixon-Woods 2003). The researcher must influence the natural environment of the situation as little as possible through his presence. The observations are recorded in the form of notes that can be enriched by documentary material such as photos, memos, situation reports, or material from the situation (Dixon-Woods 2003). Informal as well as structured notes and interviews of the observed persons complete the observations and help to get a holistic picture of the situation. Details in body language, facial expressions, or gestures are often important details, through which a situation can often be illuminated more precisely than through pure description (Dixon-Woods 2003). To analyze the resulting data, frequently occurring topic blocks and patterns are identified in the data to derive explanations and theories from them (Dixon-Woods 2003). The method has been used often in healthcare to describe the organization and provision of medical services from different perspectives and to identify risk factors (Cupit et al. 2018).

In this dissertation, ethnographies were used in the initial phases of research projects (P1, P3, and P4) to ground the research project in practice and assert the relevance of outcomes. Ethnographies helped us gain an understanding for different stakeholders like nurses, doctors, health care providers, medical technology providers, and their perspectives on patient trust and technology. Our ethnographical fieldwork had an influence on the design of the artifacts we then developed using design science approaches.

3.5 Experiments

Carefully designed and executed experiments continue to be one of science's most powerful methods for establishing causal relationships (Kirk 2012). The core idea of experiments is to manipulate one or several independent variables to measure their influence on a set of dependent variables. Dependent variables can be measured in many different ways. Two examples would be to ask participants to fill in self-report questionnaires or to measure the time participants need to carry out a specific task.

Furthermore, experiments are characterized by the use of controls such as randomly assigning participants to trial groups (Kirk 2012). There are different options to allocate participants to treatments (Field et al. 2012). First, there is the option to use a within-subject design (also often referred to as repeated measures design). In within-subject experiments, every participant does every treatment. Alternatively, a between-subjects design is also an option. In the between-subjects design, every experiment participant does exactly one treatment. Finally, in experiments with more than two treatments, it is also possible to do mixed designs. In this case, every participant takes part in at least two different treatments but not all available treatments. Each experimental design has unique strengths and weaknesses that should be taken into account when designing an experiment.

Within-subject designs have the advantage that no variance will be introduced to the experiment due to differences between the selected participants among treatments (Field et al. 2012). For example, one does not need to worry that general intelligence, gender, or age will vary among different treatments as the same set of participants is used in every treatment. In mixed- and between-subjects designs, this is something the researcher needs to take into account. Typically this is accounted for by using larger sample sizes, random assignment to treatments, and using different statistical methods for the analysis of the experiment results.

One thing that needs to be taken kept in mind using within- and mixed-designs is that they introduce learning and boredom effects. This happens because participants do several experimental tasks, which can give them a knowledge advantage about an experimental task when they do it the second time. Learning and boredom effects can be dealt with by changing the order in which participants do individual tasks. This does not prevent learning and boredom effects but evens out the overall effect they have on the experiment.

Scientists need to consider internal and external validity while designing experiments. Internal validity examines whether the study design, how it is conducted and how it is analyzed answers the research questions without bias. External validity examines whether the study findings can be generalized to other contexts (Andrade 2018). Roe et al. argue, that the most common approaches to empirical research - the use of naturally occurring field/market data and the use of laboratory experiments - fall on the ends of a spectrum of research approaches, and that the interior of this spectrum includes intermediary approaches such as field experiments and natural experiments (Roe/Just 2009).

Part B:
Published Articles

4 Structure for innovations: A use case taxonomy for smart glasses in service processes[1]

Title	Structure for innovations: A use case taxonomy for smart glasses in service processes
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Berkemeier, Lisa[2] (lisa.berkemeier@uni-osnabrueck.de) Zobel, Benedikt[2] (benedikt.zobel@uni-osnabrueck.de) Huck-Fries, Veronika[1] (veronika.fries@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) Remmers, Hartmut[2] (remmers@uni-osnabrueck.de) Thomas, Oliver[2] (oliver.thomas@uni-osnabrueck.de) Krcmar, Helmut[1] (krcmar@in.tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany [2] Osnabrück University Neuer Graben, 49074 Osnabrück, Germany
Publication	Multikonferenz Wirtschaftsinformatik, Lüneburg 2018
Status	Published
Contribution of first author	Problem definition, data collection, literature search and analysis, interpretation, reporting

Table 6. Fact Sheet Publication P1

Abstract

The evolution of smart glasses and AR technology holds potential for support of mobile service processes. Yet, little research has focused on systematic identification of potential use cases. In this article, we present a use case taxonomy derived from multiple case studies employing literature search, ethnographies, interviews and focus groups from the domains of nursing, maintenance and logistics. Building upon the identified use cases we propose a framework of task-technology fit for smart glasses. The taxonomy in combination with the framework will

[1] The article is provided in the Appendix in its original format.

allow researchers and practitioners to identify smart glass use cases that are of inter-domain relevance. Moreover, our artefacts enable a structured approach for identification and assessment of potential smart glass use cases without in-depth knowledge of the technology.

Keywords: Smart Glasses, Taxonomy, Service, Health Care, Maintenance, Logistics

5 CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities[2]

Title	CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) Krcmar, Helmut[1] (krcmar@in.tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany
Publication	Conference on Design Science Research in Information Systems (DESRIST), 2017
Status	Published
Contribution of first author	Literature review, Problem definition, research design, data collection and analysis, interpretation, reporting

Table 7. Fact Sheet Publication P2

Abstract

Lack of proper hand hygiene is often the source of hospital-acquired infections. Despite many efforts, on average, health care workers still perform hand hygiene in less than 50% of the occasions in which they must. Serious games have been used successfully to achieve behavioral change in other health care domains. To tackle the complex problem of hand hygiene compliance, we followed a design science research approach combining the build-phase with three evaluation cycles. In this paper, we present a preliminary design of a serious game to explore the possibilities of achieving better hand hygiene compliance of health care workers.

Keywords: hand hygiene, serious games, augmented reality, health care.

[2] The article is provided in the Appendix in its original format.

6 Development of a smart glass application for wound management[3]

Title	Development of a smart glass application for wound management
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) Krcmar, Helmut[1] (krcmar@in.tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany
Publication	Conference on Design Science Research in Information Systems (DESRIST), 2019
Status	Published
Contribution of first author	Literature review, Problem definition, research design, data collection and analysis, interpretation, reporting

Table 8. Fact Sheet Publication P3

Abstract

Treatment of chronic wounds is a challenging task for health care professionals. When treating chronic wounds, accurate documentation of wound development via photos, measurements, and written descriptions are crucial for monitoring the healing progress over time and choosing the right wound treatment. Currently, however, wound documentation is often perceived as inaccurate and incomplete. In this research, we follow a user-centered design science approach to develop a smart glass-based wound documentation system to support healthcare workers. Through ethnographic fieldwork, interviews, and prototype tests with focus groups, we find that smart glass applications hold potential for improving the wound documentation process because they allow for hands-free documentation at the point of care.

Keywords: augmented reality, health care, wound management, design science, smart glasses

[3] The article is provided in the Appendix in its original format.

7 Digital transformation in health care: Augmented reality for hands-free service innovation[4]

Title	Digital transformation in health care: Augmented reality for hands-free service innovation
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) Krcmar, Helmut[1] (krcmar@in.tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany
Publication	Information Systems Frontiers (ISF), 2019
Status	Published
Contribution of first author	Problem definition, research design, data analysis, interpretation, reporting

Table 9. Fact Sheet Publication P4

Abstract

Health care professionals regularly require access to information systems throughout their daily work. However, existing smart devices like smartphones and tablets are difficult to use at the point of care because health care professionals require both hands during their work. Following a design science research approach, including ethnographic fieldwork and prototype tests with focus groups, we find that Augmented Reality smart glass applications offer the potential for service innovation in the health care sector. Our smart glass prototype supports health care professionals during wound treatment by allowing them to document procedures hands-free while they perform them. Furthermore, we investigate the use of audio-based and physical interaction with smart glasses in a within-subjects design experiment.

Keywords: augmented reality, health care, digital transformation, smart devices, smart services

[4] The article is provided in the Appendix in its original format.

8 Conceptualizing passive trust: the case of smart glasses in healthcare[5]

Title	Conceptualizing passive trust: the case of smart glasses in healthcare
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Obermaier, Julia[1] (kai.klinker@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany
Publication	European Conference on Information Systems (ECIS), 2019
Status	Published
Contribution of first author	Literature review, Problem definition, research design, interpretation, reporting

Table 10. Fact Sheet Publication P5

Abstract

In recent years the digitization of healthcare has been moving forward. Emerging technologies, such as smart glasses, are being tested for allowing healthcare workers information access at the point of care while being able to work hands-free. Yet it remains unclear how the use of smart glasses will affect the trust relationship between patients and caregivers. The patient is not an active user of the smart glasses but is nevertheless dependent on outcomes influenced by the smart glasses. The patient, therefore, becomes a passive trustor of this technology. Building upon existing trust research literature, we present a research model and extend it by interviewing 20 patients about their experiences with caregivers and their perceptions regarding the use of smart glasses in healthcare. We find that communication with patients is a key driver of passive trust in technology and trust in caregivers. This research contributes to a better understanding of the trust relationship between patients and caregivers and provides insights into the construct of passive trust in technology. To extend the qualitative data analysis, future research should investigate the extent of the acceptance of smart glasses by patients within healthcare facilities.

Keywords: smart glasses, passive trust, health care

[5] The article is provided in the Appendix in its original format.

9 Smart Glasses in Health Care: A Patient Trust Perspective[6]

Title	Smart Glasses in Health Care: A Patient Trust Perspective
Authors	Klinker, Kai[1] (kai.klinker@tum.de) Wiesche, Manuel[1] (wiesche@tum.de) Krcmar, Helmut[1] (krcmar@in.tum.de) [1] Technische Universität München, Chair for Information Systems, Boltzmannstraße 3, 85748 Garching, Germany
Publication	Hawaii International Conference on System Sciences (HICSS), 2020
Status	Published
Contribution of first author	Literature review, Problem definition, research design, data collection and analysis, interpretation, reporting

Table 11. Fact Sheet Publication P6

Abstract

Digitization in the health care sector is striving forward. Wearable technologies like smart glasses are being evaluated for providing hands-free and septic-safe access to information systems at the point of care. While smart glasses hold the potential to make service processes more efficient and effective, it is unclear whether patients would opt-in to treatments involving smart glasses. Patients are not active users of smart glasses but are nevertheless affected of outcomes produced by the symbiosis of health care workers and smart glasses. Using an online survey with 437 respondents, we find that it is important to properly explain to patients why smart glasses are being used and to proactively address data privacy concerns. Otherwise, smart glasses can significantly increase risk perceptions, reduce patients' estimates of health care workers' abilities, and decrease patients' willingness to opt-in to medical procedures.

[6] The article is provided in the Appendix in its original format.

Part C

10 Summary of Results

To address the three research questions of this thesis, we used six publications. We summarize the findings of the three research questions in the following by describing how each of the publications addresses a particular issue of a research question. The subsequent section discusses these results.

RQ1: *How can use cases for augmented reality smart glass applications in health care be identified systematically?*

A use case taxonomy for smart glasses in service processes. Based on ethnographies, interviews, focus group meetings, and literature review, we identified 76 use cases for smart glasses in the domains of health care, maintenance, and logistics (P1). We developed a taxonomy that clusters the use cases into several overarching themes. Furthermore, we proposed a framework that integrates smart glass technology into an existing task-technology fit framework for mobile technologies. Looking at the themes identified in the taxonomy can help practitioners and researchers identify potential use cases in their application domain. Once a set of potential use cases has been identified, the developed framework can help to evaluate the potential of implementing a smart glass supported service process.

RQ2: *What design recommendations can be deduced for mobile health applications?*

Designing a serious game to foster hand hygiene compliance. Based on design objectives from the literature, we used a design science approach to design, develop and evaluate a serious game artifact targeted at improving hand hygiene compliance (P2). The novelty of the project lied in the approach to employ a serious game that has parallels to health care workers daily routine. Since the game provides instant feedback when hand hygiene errors are made, users can test and implement methods for themselves that will help them perform proper hand hygiene under stress.

Development of a Smart Glass Application for Wound Management. Based on requirements derived from literature, ethnographic studies, and interviews, we followed a design science approach to iteratively develop an artifact that supports health care workers in documenting chronic wounds. We found that wound documentation systems need to be usable hands-free and at the point of care. Hands-free use of technology is necessary because health care workers need to stabilize and interact with the patient while measuring the wound's size and taking a photo of it. Our proposed solution incorporates a smart glass application that is used for photo documentation at the point of care and a tablet that is used for data analysis and entry of text data. Several versions of this system have been evaluated with health care workers, and the insights gathered through those evaluations helped to improve the design and justify design decisions.

Technology interaction methods for hands-free services. Based on an experiment with health care workers using smart glasses, we tested different methods for hands-free technology interaction. Health care workers often need both hands for treating patients and thus cannot interact with technology using their hands. Furthermore, septic-safe use of technology is an important aspect that also implies that technologies should not be touched during patient visits. Thus, we tested the use of voice commands and eye blinking with smart glasses in a within-subjects design experiment. We found that smart glass based documentation systems are viewed significantly more favorable in terms of performance expectancy, behavioral intention, and satisfaction compared to existing documentation processes. Furthermore, we deduce that some wound managers did not like eye blinking because repeated blinking is uncomfortable with contact lenses. However, generally speaking, health care professionals seem to prefer eye blinking over voice commands.

RQ3: *How does health care workers' use of Augmented Reality smart glasses affect trusting beliefs of patients?*

Conceptualizing passive trust. To answer the third research question, we started by conducting semi-structured interviews with patients on their experiences in health care facilities using the critical incident technique. We were especially interested in incidents that lead to patients trusting or distrusting doctors, medical technology, or the health system as a whole. Based on insights from the interviews and a review of the scientific literature, we developed a research model of passive trust in technology. The context of passive trust of technology can be described as follows: Patients are not active users of many medical technologies but are nevertheless dependent on outcomes influenced by medical technologies. The patient, therefore, becomes a passive trustor of medical technologies. By analyzing the interviews, we confirmed that many constructs we had already identified in the scientific literature play an important role. Furthermore, we found also that communication with patients is a key driver of passive trust in technology and trust in caregivers.

Quantitative research on passive trust.

To deepen our understanding of which factors drive passive trust we conducted an online survey. We recruited participants using online advertisements on Facebook. Participants were then randomly assigned to one of two treatments. One treatment was a control treatment, while the other contained an experimental manipulation. Both treatments asked the participants to read a scenario and to give their opinion on the scenario afterward using Likert-scale type answers to questions. The experimental manipulation was that the scenario in the manipulation group included the use of smart glasses during a patient visit. In contrast, the same patient visit in the control group was described as a regular patient visit without smart glasses. The results of the survey confirmed that perceived usefulness and privacy concerns are important factors regarding smart glasses, trust in caregivers, and opt-in intentions. Furthermore, the results indicate that gender and age differences play a notable role in this context. Table 12 gives an overview of the key findings of this thesis.

P	RQ	Findings
P1	RQ1	▪ Smart glasses are an emerging technology with many potential use cases in the service sector. ▪ In total, we identified 76 use cases for smart glasses in the application domains of logistics, health care, and maintenance ▪ These use cases can be fit into 11 application areas for smart glass technologies ▪ Based on the 11 categories we developed a taxonomy of smart glass use cases for the domains of health care, maintenance, and logistics ▪ Furthermore, we developed a task technology fit framework for assessing the digitization potential of a process using Augmented Reality smart glasses.
P2	RQ2	▪ Use of an iterative design science research approach is a promising method to identify design recommendations ▪ Serious games are a promising approach to achieve behavioral change ▪ Providing a simulation environment for practicing hand hygiene involving a second task helps to internalize of adherence methods under stress ▪ Instant feedback on errors is essential for the learning process
P3	RQ2	▪ Hands-free technology interaction is one of the main advantages of smart glasses in the health-care sector ▪ Wound documentation should take place at the point of care ▪ Hand-held devices and PCs can be used more efficiently for inputting text than smart glasses ▪ Usage of a combination of smart glasses and PC/hand-held devices is optimal for performing hands-free documentation at the point of care and for manipulating text data in the nursing room.
P4	RQ2	▪ A necessary precondition for the usage of AR smart glasses in the health care sector is technology acceptance of such devices by the health care workers ▪ Health care workers require a measurement feature that allows them to measure wounds hands-free ▪ Our evaluation results suggest that health care workers would accept and be satisfied with using smart glasses for wound documentation. ▪ Health care workers' favorite technology interaction method (voice commands or eye blinking) is subject to individual preference, but eye blinking was generally preferred. ▪ This implies that eye blinking in combination with gaze is a viable solution for hands-free technology interaction in the health care context
P5	RQ3	▪ Existing trust research has not focused on the perspective of passive users of information systems such as patients ▪ It is unclear how the use of smart glasses will affect the trust relationship between patients and health care professionals ▪ By interviewing 20 patients, we find that communication with patients is a key driver of passive trust in technology and trust in caregivers ▪ We derived a research model for passive trust-based the interpersonal trust model by Mayer et al. (Mayer et al. 1995)

Table 12. Overview on key results

P	RQ	Findings
P6	RQ3	▪ Items for constructs in the research model were either adapted from scientific literature or self-developed and tested in an online survey ▪ In total, 437 valid datasets could be collected by participants that took the online survey. ▪ The resulting data confirms that both interpersonal and technological aspects play a role in this context ▪ As predicted by the interpersonal trust model, the results confirm that ability, benevolence, and integrity predict trust in the caregiver and opt-in intentions to medical procedures. ▪ Furthermore, we confirmed patients' perceived usefulness and privacy concerns as relevant factors for modeling technological aspects of smart glasses. ▪ We conclude from this that it is essential to adequately explain to patients why smart glasses are being used and to address data privacy concerns proactively.

Table 12. Continued

11 Discussion

Based on the summary of our results, in the following, we discuss findings against the background of the related body of knowledge.

11.1 Systematic identification of use cases for smart glasses and augmented reality

In section 2.1 of this thesis, we describe the increasing pace of promising developments in smart glasses and AR technology over the last years. We conclude that the field is advancing from a focus on enabling technologies such as tracking algorithms and efficient on-board GPUs towards research on how smart glass and AR technologies can be applied to support service processes in real-world settings. Against this background, a research gap emerged, which we defined using the following research question: *How can use cases for augmented reality smart glass applications in health care be identified systematically?*

We contribute to the scientific discussion on this topic on several levels. First of all, we have identified 76 use cases across three different service domains (P1). Using the identified use cases we developed a cross-domain taxonomy consisting of 11 categories of use cases. The taxonomy is presented in Table 13. The taxonomy shows that it is possible to categorize existing use cases into a subset of generalizable categories. This introduces opportunities for future application development in two ways. First, the taxonomy can be used as a source of inspiration to identify use cases in new domains. Second, application developers can use the identified categories to develop applications that can be built with a larger subset of use cases in mind.

Category	Description
Communication	Helps to get or send information to the operation location
Documentation	Provides the possibility to document processes on the fly
Process guidance	Provides guiding information
Education	Use smart glasses to teach employees
Alerts	Attracts user attention for urgent information or warning
Data Visualization	Shows helpful augmented information in-situ
Automatic Control	Reduces error rates in error-prone processes
Inventory management & automatic ordering	Automatically keep track of objects and resources to enable optimal consumption, usage, and re-ordering
Resource allocation	Manage limited capacities, e.g., time, staff
Text handling	Helps users generate or interpret written language
Navigation	Providing routes and action sequences

Table 13: Taxonomy of use cases for smart glasses and AR applications

Our next contribution to the scientific discussion on the systematic identification of smart glasses and AR use cases is a framework for task-technology fit developed in P1. Figure 12 shows a depiction of the developed framework. The framework was developed as an extension to a general framework on task technology fit that compares IT work in desk environments with mobile environments (Liang et al. 2007). Furthermore, based on the framework, we developed a set of questions that can help to evaluate the potential of smart glass and AR technologies. The developed questions are shown in Table 14. Used in conjunction, the taxonomy (Table 13), the framework (Figure 12), and the evaluation questions (Table 14) can guide digitization efforts using smart glasses and AR technology. The taxonomy helps in identifying use cases, while the framework and the evaluation questions help to estimate business potential.

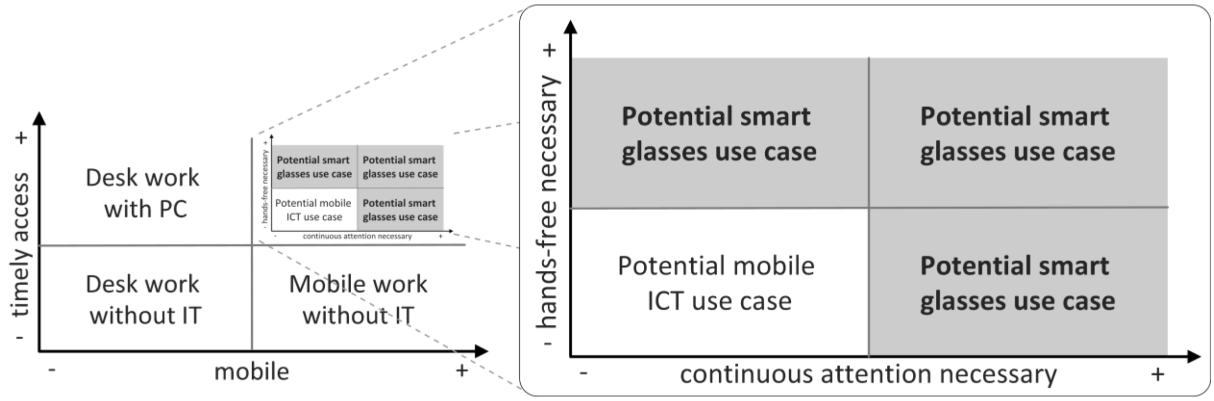

Figure 12: Framework for task-technology fit of smart glasses and AR technologies

Question	*No*	*Yes*
Are both hands necessary for the execution of the process?	--	++
Do the activities require timely information access?	--	++
Do the activities demand high mobility?	--	++
Is continuous attention needed?	--	++
Can in- and outputs be depicted visually and/or auditory?	-	+
Is a simple visualization possible?	-	+
Is network-connectivity possible throughout the site?	-	+
Is the amount of information needed also displayable?	-	+
Are speech-commands possible?	-	+
Is content already digitally available?	-	+
Can GPS and localization improve the process?	**o**	+
Can video-communication support the process?	**o**	+
Is the social environment open towards new technology?	-	**o**
Can technology-harmful external factors (e.g. dust) be eliminated?	-	**o**

-- prohibitive - obstructive **o** neutral + favorable ++ required

Table 14: Questions for task-technology fit evaluation

11.2 Design recommendations for mobile health applications

We conducted three studies that allow us to discuss design recommendations for mHealth applications in different contexts (P2 – P4). The studies we did were focused on two topics: The first topic was focused on the development of a serious game to improve hand hygiene compliance. The second topic was the development of an application to support the process of wound management in German health care facilities.

The health care domain inhibits unique characteristics in every country. Furthermore, successful interventions need to take into account the target population and specific characteristics of the topic the artifact is being developed for. We think that following design science approaches was a good choice in both contexts. Design science research provided an appropriate methodological framework for us to incorporate practical relevance and scientific rigor and to come up with solutions that are tailored to individual contexts. In the following, we discuss how we contribute to the scientific discussion on individual topics.

Hand hygiene compliance is a topic with a history ranging back until early eighteen hundreds (Best/Neuhauser 2004). Yet, studies show that the estimated number of hospital-acquired infections in the European Union is 4.5 million annually, leading directly to around 37.000 deaths, 16 million extra days of hospital stay, and 110.000 indirect deaths (Zingg et al. 2015; Zarb et al. 2012). Since health care workers wash their hands in less than 50% of the appropriate moments, it is worth looking into interventions that can help improving hand hygiene compliance(Creedon 2005).

Looking back on our project, we argue that serious games are a promising approach to improve hand hygiene compliance. In Germany, health care workers have mandatory hand hygiene compliance training every year. Yet, most practitioners we talked to showed little interest in these mandatory sessions and believed that they have little or no lasting impact. On the other hand, when testing our games, it was always easy for us to find participants because people enjoy playing games.

Regarding existing design principles on serious games, there is a consensus in the scientific literature that games need to be fun for the user (McGonigal 2012). However, the use of gamification and serious game design principles in mHealth applications is yet a burgeoning innovation practice (Miller et al. 2016). Thus we focused our efforts on developing a game that is fun to play. While developing the game, we learned several lessons. In the first iterations of the project, we did not differentiate between different skill levels of users and also did not provide training tutorials. This lead to some users getting frustrated because they felt overwhelmed and others getting bored because it was too easy for them. Offering a range of difficulty and tutorial levels improved the overall game experience. Furthermore, we learned that it is essential to show the user immediately when a hygiene error is made and what the error was. This helped them to link actions to outcomes right away and helps them to learn faster.

In the wound management context, we learned that wound documentation should take place at the point of care. Otherwise, the resulting documentation is often inaccurate because health care professionals do not remember wound details accurately. However, in order to perform the documentation at the point of care, health care professionals require technological assistance that lets them document hands-free. Two challenges that arise from these insights are that health care professionals need to be able to interact with the technology hands-free and have to be able to measure the wound size without having to touch a ruler. Through iterative development and testing of artifacts, we were able to come up with a design using a combination of smart glasses and a tablet that is able to meet all of these requirements. Furthermore, data from an experiment we have conducted implies that eye blinking could be a promising candidate for interacting with the smart glass.

Yet several challenges remain. To be able to use such a system in practice, the smart glasses and the tablet application need to be integrated with the existing health information system. Furthermore, during evaluations of the smart glasses with health care professionals, we discovered that the patient perspective on smart glasses is unknown. Trusting relationships between health care workers and patients are essential for many aspects of the health care system. Health care professionals wearing smart glasses might make patients anxious and reduce trust in medical personnel. This is why we also decided to conduct research on the patient perspective on health care professional's use of smart glasses.

11.3 Passive trust and patients' perspective on augmented reality smart glasses

Over the last years, research into patient's trusting perceptions about the use of medical technology during their treatment has emerged. The conceptual groundwork on this topic has been shaped by the concept of passive trust, which was popularized by Montague et al. Montague et al., define a passive user as an individual with limited control over the technologies and IT artifacts used in a system (Xu and Montague, 2012). Nevertheless, passive users are directly affected by the results and the outcome of technology use. A passive user can observe the actions and interactions of the active user with the technology and use these perceptions to assess the functionality and reliability of a technology. Communication of the passive user with the system is only conditionally possible or is moderated by the active user (Inbar and Tractinsky, 2009). In the context of health care, patients are passive users, and health care workers are the active users of technology. The limited influence of the passive user inherent in an inability to control the system can lead to insecurity and anxiety in the interaction (Inbar and Tractinsky, 2009). Although passive trust has been mentioned in various contexts, little empirical research on this topic can be found. Moreover, passive trust has not been integrated with and delimited by existing trust research.

Trust in people, as well as trust in technological artifacts, are well-established research topics in the IS literature (Söllner et al. 2016). Yet, very little IS research has focused on the passive user perspective. This finding is supported by Söllner et al., who find that IS research on trust has mainly focused on the trust relationship between the user and the information system itself, largely neglecting that other targets of trust might also drive IS use from a user's point of view (Söllner, Hoffmann and Leimeister, 2016).

Two publications in this dissertation project (P5, P6) are targeted at this research gap. The interviews conducted in P5 show that patients have mixed feelings about the use of smart glasses in delivering their care. The interviewees commented that initial eye contact is essential for them to build trust in the caregiver. This supports results of Riedl et al., who argue that human faces help to build trust (Riedl et al., 2014). The results also show that patients want to retain as much control as possible during treatment. Extensive patient education and information on measures, diagnoses, and applied technologies give the patient the feeling of being able to control the situation. Technology characteristics such as shape, appearance, and size have also been mentioned as a potential dimension of passive trust in technology. It is also possible that further constructs, which are relevant to the context of passive trust, have not been uncovered in these early stages of research.

The interview results also provide insights into the relationship between patient and caregiver. The qualitative analysis of the interviews confirmed competence, integrity, benevolence as relevant interpersonal trust dimensions (Mayer et al., 1995) and identified communication skills as an additional dimension of trust-building for health care professionals. The results suggest that Mayer's interpersonal model of trust (Mayer et al. 1995) also holds in the passive trust context. However, the interview results also emphasize communication as an influencing factor more than we initially assumed.

When reflecting upon what can be learned from the interviews in P5, we conclude that perceptions of human traits, as well as the technology, are both likely to be the main factors. As positive and negative experiences mentioned by patients were mainly related to information and communication, we decided to conduct further research focused on encounters with health care professionals and patients in the field and how smart glasses change such encounters.

Building on the results from the exploratory interviews in P5, we developed and empirically tested a research model for passive trust in P6 (see Figure 13). Using an online survey with 437 valid responses, we were able to confirm most parts of the proposed model.

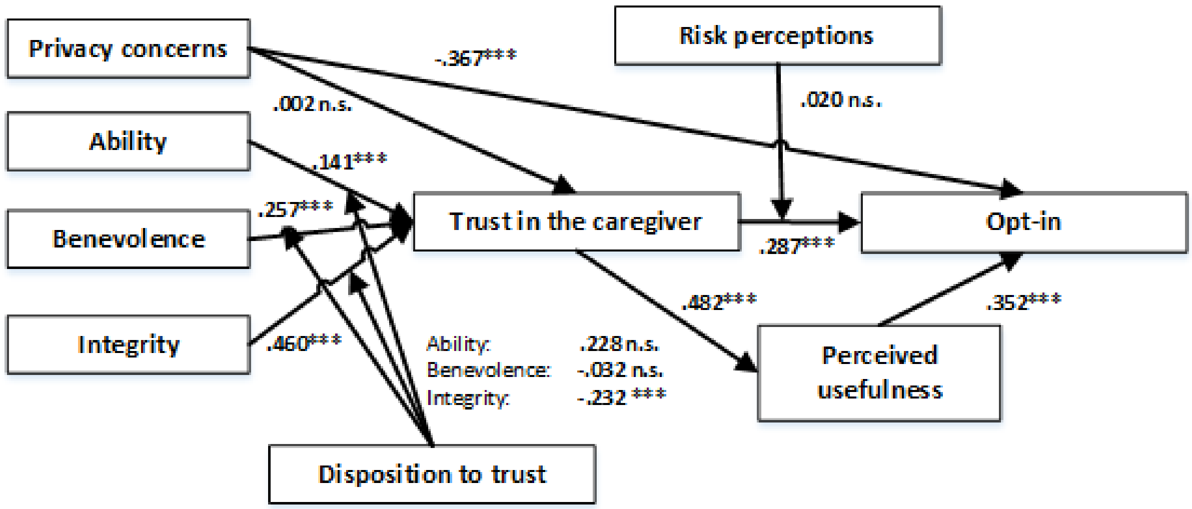

Figure 13: Research model for passive trust in technology using standardized coefficients (p-value significance level: *.05, **.01, *.001**

The quantitative results of study P6 have unveiled several insights into the inner workings of passive trust in the health care sector. We were able to show that perceived usefulness and privacy concerns are important factors regarding the use of smart glasses, trust in health care professionals and opt-in intentions. As expected, a mixture of interpersonal trust and technological aspects play a role in explaining the opt-in intentions of patients.

Further, we found interesting results regarding gender and smart glasses, similar to a study conducted by Koelle et al. (Koelle et al. 2015). They found that females are more likely to express negative feelings about the use of smart glasses (Koelle et al. 2015). In our study, female participants viewed the use of smart glasses significantly more negatively than male participants in some dimensions. Females reported significantly higher risk perceptions and privacy concerns regarding the use of smart glasses in the presented scenario than the male participants. Furthermore, females perceived the smart glasses to be less useful and were less willing to opt-in to procedures involving smart glasses than men.

Interestingly our findings regarding age differ with the results reported by other studies in which older patients are generally more inclined to trust (Hillen et al. 2015). In our study, age was negatively correlated with the disposition to trust and trust in the caregiver, which was presented in the scenario. Moreover, older participants rated the benevolence and integrity significantly lower than younger participants. Interestingly, none of these factors are technology-related. Instead, they are all clustered on an interpersonal level.

12 Limitations

Several of our studies have limitations. Most of them are related to **sample sizes** or **recruiting strategies** for experiment participants. For instance, in P6, we had an unequal gender representation in our sample. 84% of the study's participants were female. This is probably due to our recruiting strategy, which was to use advertisements on Facebook to acquire study participants. Thus, despite being statistically significant, the results pertaining to gender should be regarded with caution and be treated as preliminary results.

Moreover, in P2, the participants of the study were predominantly students recruited from a computer science department. Participants from other age groups and study backgrounds might perform differently on the given tasks. Looking at the experiment that we used to validate our final design of the wound documentation application (P4) and to evaluate different technology interaction methods, we also found limitations. First, we were able to recruit 45 wound documentation experts to participate in our experiment. In most cases, we traveled to individual health care facilities to conduct the experiment with participants at their place of work. This gave us less control over the environment as compared to a laboratory experiment and may have had an influence on the **internal validity** of the experiment. Furthermore, wound documentation processes are not standardized and differ among health care providers. Thus we were not able to align our artifacts with the participants' documentation habits.

On a more general level, most of our research studies were focused on German health care providers (P2 –P6). The legal and practical context pertaining to most of our research topics is likely to differ in other countries. We would thus argue that the **generalizability** of our results to the contexts of other health care systems is limited. Transferring insights from our studies to other settings requires a careful case-to-case analysis about what the target context has in common with Germany.

13 Implications

13.1 Implications for Theory

Smart glasses are an emerging technology with many potential use cases in the service sector. Their main potential lies in providing mobile information access while being able to use both hands. In this thesis, we have proposed a cross-domain classification framework for use cases (P1). Researchers can use the framework for systematic identification of digitization potentials in existing services and the implementation of assistive systems. Our research contributes to the fields of augmented reality, wearable computing, and service science by providing a **cross-domain classification taxonomy for smart glass applications** and a **framework for assessing task-technology fit**. Researchers can use these artifacts to identify use cases that are of practical relevance to several domains. Our taxonomy provides a structured approach for digitization efforts of service processes. Researchers can identify use cases in different service domains by looking at the categories and specific examples of our taxonomy. Starting from there, they can find similar digitization potentials in the domain. Once potential processes have been identified, our task-technology fit framework for smart glasses can help to assess the viability of smart glass support for a given task.

Health care providers all over the world are faced with the challenge of improving patient outcomes while containing costs. The digital transformation is recognized as a critical component to tackle this challenge (Gopal et al. 2019). The health care sector, and specifically, **the process of wound management,** are well-established problem contexts that continue to inhibit low levels of digital process support. Due to hygienic requirements, hands-free technology interaction is often required in the health care sector (Hatscher et al. 2017). Yet, established smart devices like smartphones and tablets are not an optimal fit due to hygienic and practical reasons. However, our work indicates that smart glasses have potential for supporting health care processes. Since it is possible to use smart glasses hands-free, we deem the evaluation of smart glasses for process improvements in the health care sector to be a worthy research endeavor.

We used a design science approach to investigate **design principles for AR smart glasses** for usage in health care and have built several instantiations of wound management artifacts. From evaluations with these artifacts, we have derived design knowledge that we consider to be contributions that specifically apply to the wound management process (P3 and P4). First, we were able to confirm that hand-held devices are not viewed favorably by health care workers for the process of wound management. Second, it became apparent that health care workers prefer to fill in the wound documentation in the patient's room while being able to look at the wound. Third, the evaluation of our two smart glass prototypes showed that health care workers require a measurement feature that allows them to measure wounds hands-free. Finally, our evaluation results suggest that health care workers would accept and be satisfied with using smart glasses for wound documentation.

Our studies on the wound documentation process further allow us to put forward design principles that are not limited to the wound management context but pertain to the broader context of hands-free technology interaction. Previous studies in the fields of 3D-User Interfaces and AR have pointed out that real-world evaluations on usability and effectiveness of different technology interaction methods are necessary (Billinghurst et al. 2015; Datcu et al. 2015). Our results imply that **eye blinking, in combination with gaze,** is a viable solution for hands-free technology interaction in the health care context. However, our study also shows that the preferred technology interaction methods are subject to individual preference. A possible solution to address this would be to offer alternative technology interaction modalities.

Furthermore, we contribute to theory by conducting **exploratory work on passive trust**. To the best of our knowledge, only very little research has been done on this topic. The constructs that drive passive trust are still elusive. While our research shows that several parts of the interpersonal trust literature can be reused for the passive trust context, new constructs need to be developed to account for the technological influences. Our research makes early steps towards this end by **developing an opt-in construct** and **testing various well-established constructs** from the IS trust literature to the context of passive trust.

13.2 Implications for Practice

This thesis has several implications for practice, which practitioners can mostly apply when identifying and implementing use cases for smart glasses in the health care domain. Smart glasses are an emerging technology with many potential use cases in the service sector. Their main potential lies in providing mobile information access while being able to use both hands. Our research contributes to practice by providing a c**ross-domain classification taxonomy** for smart glass applications and a **framework for assessing task-technology fit**. Practitioners can use these artifacts to identify use cases that are of practical relevance to several domains. Our taxonomy provides a structured approach for digitization efforts of service processes. Practitioners from different service domains can identify use cases in their field by looking at the categories and specific examples of our taxonomy. Starting from there, they can find similar digitization potentials in their domain without needing prior knowledge about smart glasses. Once potential processes have been identified, our task-technology fit framework for smart glasses can help to assess the viability of smart glass support for a given task.

The demographic change and increased life expectancy in our society will likely increase the demand for health care services in the future. Therefore, more jobs are likely to be created in the health care sector. Patient care is an integral part of health care systems (Chandwani 2017). Yet, many health care facilities are already lacking personnel. One way of making job profiles in health care more attractive could be the transformation of existing service systems to smart services systems. Positive innovation cases could incentivize health care providers to invest further into new innovative approaches to catch up to digitization levels of other service domains. Our research underlines that AR smart glasses and mHealth applications are promising tools for supporting health care processes. We have conducted three in-depth studies (P2-P4) that provide **practical examples** and **design principles** for supporting health care services with mHealth technology. Finally, the practical examples and the proposed design principles can be used by smart glass manufacturers and software developers to design mHealth solutions tailored to the needs of health care workers.

14 Future Research

In the course of our research on AR smart glasses in health care, several new research questions emerged, which are out of the scope of this thesis but provide fruitful avenues for future research.

Data security and privacy research. Throughout our research on systematic identifications of use cases in P1, we noticed that in the logistics, health care maintenance domains, data security is of central importance. Services in industry and health care often work with highly sensitive data that needs to be kept confidential. This is a complicated task since most of the use cases we have listed imply the use of cameras and networking technology. Sometimes even with external partners, such as machine suppliers or doctors. The recent advances of smart glasses technology hold promising potentials for improving service processes by providing ubiquitous access to information while working hands-free. However, advances in smart glass technology also raise long-term impact questions. Future generations of these devices will probably make use of built-in cameras that are continuously recording, using computer algorithms for tracking humans and displays that only show information to its user. The diffusion of such technology into the consumer market will likely have an impact on our daily lives. Future research on privacy and ethical requirements for this pervasive technology are needed.

Design science research on further use cases in health care and other domains. Within our research, we focused on individual use cases within the health care sector. To digitally transform the health care sector, identification of further use cases and design science research to implement these use cases is required. Furthermore, use cases similar to wound management exist in other service domains. For instance, maintenance technicians need to regularly document maintenance activities they perform on machines, where mobile and hands-free information access is helpful. Future research could build upon our technology interaction recommendations to build helpful artifacts in these domains.

Research opportunities combining smart glasses and artificial intelligence. The usage of smart glasses in smart service systems implies interesting options for artificial intelligence. Artificial intelligence can be used to detect and automate process steps. For instance, the smart glass cameras could be used to recognize a patient's wound, automatically measure its size and save it to the patient's health record. Building upon such capabilities, it might be possible to monitor, prioritize, and distribute tasks within a smart service system of health care workers wearing smart glasses. Future work looking into technical aspects of combining these two promising technologies thus has potential.

Future research on passive trust. Research on passive trust is still in a very early stage. Our research shows that interpersonal, as well as technological aspects, play a role in this context. However, we made some surprising observations that should be investigated by future work. For instance, P6 showed that privacy concerns regarding smart glasses did not have a negative effect on trust in the caregiver. We hypothesize that the reason for this might be that patients do not think that medical personnel would be inclined to misuse their data. Qualitative research with patients could shed more light on this finding. Furthermore, while we were able to show that privacy concerns and perceived usefulness are essential factors in the context of passive trust, it is quite likely that we have missed other important factors. Several comments suggest that the empathy displayed by the caregiver could be relevant. This would also be in line with prior findings in the medical literature that highlight the role of communication in health care (Strandås/Bondas 2018). Finally, P5 and P6 focused on the use of smart glasses in the health care sector. However, the notion of passive trust is much broader. In order to be able to make generalizations about passive trust in different contexts and technologies, further research is needed. We encourage fellow researchers to conduct empirical research on use cases in other domains and to compare the results to ours.

15 Conclusion

The evolution of smart glasses and augmented reality technology holds potential for support of mobile service processes. Yet, little research has focused on the systematic identification and implementation of potential use cases in practice. In this thesis, we have developed frameworks and taxonomies that can guide researchers and practitioners during the early phases of use case identification. By describing several research projects using design science approaches in the health care domain, we provide examples that show how use cases can be implemented. Furthermore, we have summarized the insights derived throughout those projects into design principles that can provide further guidance to digitization projects. Throughout the projects, we learned that not only technological but also human factors play an essential role in the adoption of digital solutions. In many service industries, trusting relationships between the person wearing smart glasses and onlookers is required. For instance, in the health care industry, it is essential that patients trust medical professionals. We contribute to the scientific discussion on this topic by transferring models and constructs from the IS trust literature and conducting empirical studies that measure their applicability to this context. We hope that our results spark further research on augmented reality smart glasses in practical settings.

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Appendix:

Appendix A: Semi-structured interview guide used in P5

Patientenbefragung zu Smart-Glasses in der Pflege

Befragten-Nr.:

Geschlecht: ☐ männlich ☐ weiblich ☐ anderes

Alter: ______________________________

Höchster Abschluss: ______________________________

Computererfahrung in Jahren: ______________________________

Computerfähigkeiten:

Keine				*Sehr gut*	*Kann ich nicht beurteilen*
0	1	2	3	4	☐

Erfahrung mit Smart-Glasses:

Keine				*Sehr viel*	*Kann ich nicht beurteilen*
0	1	2	3	4	☐

Erfahrung mit Augmented Reality:

Keine				*Sehr viel*	*Kann ich nicht beurteilen*
0	1	2	3	4	☐

Technik-Affinität:

Keine				*Sehr viel*	*Kann ich nicht beurteilen*
0	1	2	3	4	☐

Teil 1 – Critical Incidents

Anweisung: Versuchen Sie sich bitte an Situationen in denen medizinische Technologien in Ihrer Pflege verwendet wurden zu erinnern. Das kann alles sein, von Blutdruckmessen bis zur Nutzung eines Röntgen- oder MRT-Geräts.

1. Welche Erfahrungen hatten Sie mit dem Einsatz medizinischer Technologien in Ihrer Pflege?
   - Beschreibung der Situation
   - Was ging der Situation voran?
   - Was haben beteiligte Personen getan, dass die Situation beeinflusst hat?
   - Was war das Ergebnis der Situation?
   - Was hätte anders getan werden sollen?

2. Gab es Prozeduren, die an ihnen durchgeführt werden sollten, denen sie kritisch gegenüberstanden?
   - Beschreibung der Situation
   - Was ging der Situation voran?
   - Was haben beteiligte Personen getan, dass die Situation beeinflusst hat?
   - Was war das Ergebnis der Situation?
   - Was hätte anders getan werden sollen?

3. Haben sie immer sich an Anweisungen des medizinischen Personals gehalten?

   Ja ☐ nein ☐

   Bitte begründen Sie Ihre Antwort.
   - Beschreibung der Situation
   - Was ging der Situation voran?
   - Was haben beteiligte Personen getan, dass die Situation beeinflusst hat?
   - Was war das Ergebnis der Situation?
   - Was hätte anders getan werden sollen?

4. Sind Ihnen Situationen bei anderen Patienten aufgefallen, in denen der Einsatz von Technologie nicht standardmäßig abgelaufen ist?
   - Beschreibung der Situation
   - Was ging der Situation voran?
   - Was haben beteiligte Personen getan, dass die Situation beeinflusst hat?
   - Was war das Ergebnis der Situation?
   - Was hätte anders getan werden sollen?

Teil 2 – HoloLens zur Vermessung und Dokumentation von Wunden

Stellen Sie sich vor sie hatten eine schwere OP an der Hand und nun eine Wunde, die abheilen muss. Dafür liegen Sie ein paar Wochen im Krankenhaus. Eine Krankenschwester kommt jeden Tag mit einer neuartigen Datenbrille in ihr Zimmer.




Sie nutzt Sprachbefehle um mit der Brille zu interagieren. Mithilfe der Brille vermisst sie die Wunde und fertigt Fotos aus verschiedenen Winkeln an, um die Wunde zu Dokumentieren.

1. Was sind Ihre ersten Gedanken?

2. Würde es einen Unterschied für Sie machen, wenn die Wunde an einer anderen Stelle wäre?

   Ja ☐ nein ☐

   Bitte begründen Sie ihre Antwort.

3. Würden Sie der Methode generell zustimmen?

   Ja ☐ nein ☐

   Bitte begründen Sie Ihre Antwort.

Appendix B: Semi-structured interview guide for a think aloud evaluation used in P2

Zeitpunkt	Beschreibung	Ort	Anweisung
Begrüßung		01.13.051	Vorstellung „Herzlich willkommen zum heutigen Experiment. Im Rahmen unseres Forschungsprojektes untersuchen wir den Einsatz von Wearable Devices im Krankenhaus. Hierzu haben wir heute die Datenbrille *Microsoft Hololens* mitgebracht. Zunächst werden wir Dir eine kurze praktische Einführung an der *Microsoft Hololens* geben. Daraufhin hast Du die Gelegenheit die Hololens am Beispiel eines Spieles zum Thema Krankenhauskeime auszuprobieren. Abschließend werden wir Dir ein paar Fragen zu deinen Erfahrungen bei der Verwendung der Hololens stellen. Während des Experiments werden wir einige Teile stichpunktartig mitschreiben. Bist du damit einverstenden? Hast du noch Fragen?“
Hololens	Vorbereitung	01.13.051	Der Experimentleiter setzt die Cat Care App auf den Ausgangszustand zurück. Anschließend setzt der ExperimentteilnehmerIn sich die Hololens auf. Der Screen der Hololens wird auf einem PC gespiegelt.
Hololens	Erklärung des Spiels	01.13.051	Dem ExperimentteilnehmerIn wird der folgende Text vorgelesen „In dieser Anwendung müssen kranke Katzen gepflegt werden. Die Katzen befinden sich auf zwei verschiedenen Betten in Quarantäne. Kannst du die Katzen sehen? (Dem Probanden Zeit geben sich die Szenerie anzusehen) Mit der Zeit werden die Katzen hungrig, durstig oder verspüren ein Bedürfnis nach Zuwendung. Diese Bedürfnisse werden über den Köpfen der Tiere angezeigt (Herzen, Wassertropfen und Fressnapf). Verspürt eine Katze ein Bedürfnis, musst du die Katze mittels einer Geste aufheben und zu dem entsprechenden Tisch tragen und dort absetzen. Nach einigen Sekunden ist das entsprechende Bedürfnis der Katze dann gestillt und sie will wieder auf ihr Bett zurückgetragen werden. Um eine Katze aufzuheben musst du das schwarze Fadenkreuz in der Mitte deines Sichtfeldes auf die Katze richten und den Klicker einmal drücken. Wenn du den Klicker ein zweites Mal drückst wird die Katze losgelassen. ACHTUNG: Die Katzen auf dem linken Bett haben eine andere Krankheit als die Katzen auf dem rechten Bett und müssen deshalb in Quarantäne gehalten werden! Jedes Mal, wenn du eine Katze angefasst hast musst du dir die Hände am Waschbecken waschen, bevor du eine Katze vom anderen Bett anfasst! Siehst du wo das Waschbecken steht?“ Die Krankheiten der Katzen werden durch Punkte die um die Katzen schweben dargestellt.

			Versuche nun bitte die Katzen zu pflegen. Achte dabei bitte darauf, dass du keine Krankheiten überträgst.
Think Aloud	Verbale Einführung	01.13.051	„Um ihre Eindrücke bei der Verwendung der Hololens möglichst detailgetreu festhalten und nachvollziehen zu können, möchten wir dich bitten alle **Gedanken** die Dir während der Verwendung der Hololens in den Sinn kommen laut auszusprechen.
Nutzung Cat Care	Durchführung	01.13.051	Block zücken Der TeilnehmerIn fängt nun an mit der Hololens Applikation zu spielen. Wesentliche Vorkomnisse werden stichpunktartig aufgeschrieben.
Nutzung Cat Care	Nach Durchführung	01.13.051	Sobald der TeilnehmerIn nicht mehr spielen möchte, beginnt das Debriefing. Gedanken formulieren ist beendet.
Nutzung Cat Care	Debriefing	01.13.051	„Vielen Dank, dass du dich um die Katzen gekümmert hast. Du kannst die Brille nun abnehmen. Nun hätte ich folgende Fragen: • Was fandest du gut? • Was könnte man verbessern? • Hattest du Schwierigkeiten dich zurechtzufinden? • Hast du schon mal etwas über Krankenhauskeime gehört?
Verabschiedung		01.13.051	„Vielen Dank, dass du uns bei unserer Forschung unterstützt hast. Hast du noch Fragen?
Bei Rückfragen			Hilfe geben
>3s Rede-pause bei think aloud			„Was denken Sie gerade?“

Appendix C: Published Articles in Original Format (P1, P2, P3, P4, P5, P6)

Structure for innovations: A use case taxonomy for smart glasses in service processes

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Abstract. The evolution of smart glasses and AR technology holds potential for support of mobile service processes. Yet, little research has focused on systematic identification of potential use cases. In this article, we present a use case taxonomy derived from multiple case studies employing literature search, ethnographies, interviews and focus groups from the domains of nursing, maintenance and logistics. Building upon the identified use cases we propose a framework of task-technology fit for smart glasses. The taxonomy in combination with the framework will allow researchers and practitioners to identify smart glass use cases that are of inter-domain relevance. Moreover, our artefacts enable a structured approach for identification and assessment of potential smart glass use cases without in-depth knowledge of the technology.

Keywords: Smart Glasses, Taxonomy, Service, Health Care, Maintenance, Logistics

1 Introduction

Industrialized countries are experiencing a shift from production to services. 50% of jobs in Brazil, Russia, Japan, and Germany, as well as 75% of the labor force in the United States and the United Kingdom are currently within the service sector [1, 2]. ICTs can facilitate service innovation by playing a dual role, as both an operand (enabler) and an operant (initiator or actor) resource [3]. ICTs are used in combination with other resources (such as skills and knowledge) to leverage information use across different contexts and to create new opportunities for service exchange and for innovation [4]. Several factors complicate digitization efforts of service processes. For many use cases, hands-free interaction with Information Systems is necessary [5]. Reasons for this can be, that both hands are needed for work, hands are dirty or aseptic procedures need to be performed [6]. Thus, many mobile ICTs such as smartphones and smart watches cannot be used in many tasks [7]. As a result, workaround behaviors can often be observed [8, 9]. Furthermore, service processes are often mobile and require mobile networks [10].

The ongoing technological development of smart glasses such as Vuzix, Google Glass or Augmented Reality devices such as Microsoft HoloLens are a promising new direction for the digitization of flexible service processes [11]. Especially in situations where employees perform information-intensive activities, while having to work hands-free, smart glasses can show context-sensitive information in the user's field of view and thereby support employees in their daily work routine [12]. The main potentials for ICT applications to support service processes are expected improvements of performance, process quality, employee satisfaction and IT-enabled collaboration [13, 14]. One of the main problems for current research on smart glasses is to identify use cases for the emerging technology [15]. Prior research has focused on HCI and device-centered perspectives. The question is: "*Which field service tasks can be supported by innovative mobile technology such as wearable devices*" [15].

To address this research void, we have conducted multiple case studies in order to collect use cases for smart glasses in the domains of logistics, nursing and maintenance. Building upon prior research on task-technology fit of mobile devices and the use cases we identified, we propose a task-technology fit framework for smart glasses.

2 Related Work

The use of smart glasses has been investigated in the research fields of Augmented Reality (AR) and Wearable Computing. Augmented Reality focuses on changing the user's perception of the real world by adding information [16].

Table 1. Existing Research Topics for smart glasses

Research Area	*Topic*
Industry	Assembly [17]
	Maintenance & manufacturing [18]
	Technical customer service [19]
Health care	Hands-free photo and video documentation [20]
	Surgery [21]
	Diagnostics support [13]
	Displaying body structures [22]
	Education [23]
Logistics	Pick by vision [24]
	Hardware selection [25]
	Privacy [26]
	Usability [27]

Although this can be achieved through haptics, sound and odor, the majority of research has focused on adding virtual elements to the user's view [28]. In order to classify as an Augmented Reality application three criteria need to be met: The application needs to combine real and virtual, be interactive in real time and registered in 3D [29]. It is possible to implement AR-applications with Head-Mounted Displays, spatial displays like televisions of projectors and Hand-held devices such as tablets and smartphones [28].

Wearable computing focuses on devices that can be worn by the user. Typical devices are smart glasses, smart watches or clothes with integrated IT-devices [30]. Smart glasses integrate information in the user's field of view without an overlay of information and thereby caused limitations in the visual field [31].

The majority of existing research about smart glasses in both areas has been focused on building and evaluating prototypical applications for use cases in health care and industry [32]. Table 1 presents smart glass topics that have been researched within both domains and cites literature containing representative examples. Especially tasks with intensive information needs, that further require both hands in service delivery benefit from smart glasses-based information systems [33]. Therefore, the implementation of these systems are discussed in the fields of logistics, maintenance and health care.

3 Methodological Procedure

To investigate in which service processes smart glasses can bring benefit we carried out multiple case studies using the case study research design defined by Yin [34]. Two cases from logistics (LG), four cases within nursing (NU) and two cases from the maintenance (MT) domain were evaluated. The domain of nursing fits well to existing research from the health care field, while logistics and maintenance are typical industrial application fields. Each case relies on several sources of evidence, from which data was extracted over the last two years. Table 2 shows an overview of the project partners that were involved in our research.

As we followed a multiple method design, different methods have been applied during the inquiry to increase the breadth and range of our findings. On the strength of the specific characteristics of the different cases, we applied diverging methods for the individual problem components. Thereby four different research methods have been used with the aim of the finding's expansion [35].

Table 2. Companies involved in the Case Study

Domain	*Project Partners*	*Size*
NU	Hospitals	1 large 1 medium
	Nursing homes	1 small 1 medium 2 large
MT	Machine manufacturer	1 medium
	Airport	1 large
LG	Logistics companies	1 small 1 large

Conducting the multiple case study design, a use case was defined when an activity profited by gaining better access to information or a simpler process was achievable by the use of a smart glass application. In this section, we will briefly explain all employed methods. Starting point and supporting method during our research was a (i) literature review to find links between our findings and existing research. (ii) Shadowing served to identify potential use cases by observing workflows and every day activities. The survey was documented in the form of field notes and process models. To gain further insights on the requirements and needs of the domain experts we conducted (iii) expert interviews. We combined these interviews with evaluations of smart glass applications we were currently working on, to give the interview partners an impression of what smart glasses are capable. After the interview partners had tested one of the applications, we asked them (1) for what else they would like to use such a smart glass in their daily work routine, (2) which processes of their work were the most time consuming or difficult and (3) at what point in their daily work they would like to access information. Furthermore, we held (iv) workshops with focus groups to enable a thematic exploration of research objects from a practical perspective. We formulated a use case if it was supported by at least two independent sources from the spectrum of data sources mentioned above.

4 Taxonomy of use cases for smart glasses in service processes

In total, we found 76 use cases by applying the methodology described above. Through inductive grouping of the use cases by function and process group, we identified 11 categories of use cases, which are listed in Table 3. The inductive grouping was conducted in a group session by the authors. Use cases were printed on paper cards and rearranged into different clusters until groups emerged. In the following, we briefly describe each category in more detail and provide representative examples. A list of all use cases can be found in the Appendix.

Table 3. Taxonomy of use cases for smart glasses applications

Application Area	*Description*
Communication	Helps to get or send information to the operation location
Documentation	Provides the possibility to document processes on the fly
Process guidance	Provides guiding information
Education	Use smart glasses to teach employees
Alerts	Attracts user attention for urgent information or warning
Data Visualization	Shows helpful augmented information in-situ
Automatic Control	Reduces error rates in error-prone processes
Inventory management & automatic ordering	Automatically keep track of objects and resources to enable optimize consumption, usage and re-ordering
Resource allocation	Manage limited capacities, e.g. time, staff
Text Handling	Helps users generate or interpret written language
Navigation	Providing routes and action sequences

4.1 Description of application areas

Communication

A typical example for a communication use case can be found in maintenance. Machine manufacturers sell their machines to customers around the globe. When a machine breaks down, the entire assembly line needs to be stopped and the machine has to be repaired. Currently, maintenance technicians try to resolve problems over the phone or have to send a maintenance technician oversea. The situation could be solved more efficiently, if a worker at the assembly line could use a smart glass application with a live streaming feature. The maintenance technician can thereby see the machine over his PC and give instructions via voice or adding virtual arrows into the live stream.

Documentation

Documentation is a vital part of many processes within logistics, maintenance and health care. In many cases, documentation is needed to fulfill legal requirements.

For instance, chronic wounds of patients need to be documented on a regular basis. In the health care facilities we visited, health care professionals were not satisfied with the current process. It is time-consuming and the documentation is not perceived as accurate. A smart glass application could reduce the time required for documentation and improve its quality. Health care workers could wear smart glasses during the wound care management and fill out the wound protocol via voice commands or hand gestures without breaking the aseptic chain.

Process Guidance

In all three domains, we encountered processes, in which practitioners needed information in-situ for accurate process execution. Maintenance technicians need to know the sequence of maintenance steps and how to perform them. Health care professionals need to make sure they administer the right dosage of the right medication to patients. In logistics, small parts often need to be picked from shelves and placed in boxes, which are then send to the customer.

Education

A well-trained work force is crucial for workplace safety and efficient process execution. Teaching takes up significant time and effort within organizations. With smart glasses, it is possible to design standardized lectures that new employees can work through in the real world environment. For example, in the maintenance domain technicians often need to learn how to maintain machines they do not already know. Augmented Reality smart glasses are very adequate to support such teaching processes, because they can display step-by-step tutorials or show spatial information about hidden parts while the user has both hands free to interact with the machine.

Alerts

Process-related dangers may occur in the daily routine of the workforce. If not taken into account, these dangers may damage the worker or the goods treated. Safety alerts in wearable devices such as smart glasses can be used to remind workers of process-related dangers such as treating a patient with an infectious disease or handling hazardous goods with forklifts in warehouses.

Data Visualization

Stored data, which describes properties of goods treated, may support the working process. E.g. in maintenance displaying names of machine parts can support communication. When treating patients, it can be helpful to know biographic details, medication, diagnoses, written advice from colleagues or food preferences while talking to the patient. In logistics the loading process can be visualized to optimize the load mass. Smart glasses can provide such information in an unobtrusive manner.

Automatic Control

Automatic control of goods can be relevant to all domains in which goods have to be ordered. This is true for maintenance, healthcare and logistics. In logistics centers, incoming freight needs to be checked for damages and completeness. This can be automated by taking a picture of each parcel and scanning its barcode while being able to continue working hands-free.

Inventory Management & Automatic Ordering

Every domain with an inventory may use an inventory management and automatic ordering process if goods have to be replaced regularly. During maintenance, parts of machines often need to be replaced while maintenance workers hands are smeared with oil. Smart glasses could automate this process by simply scanning the product code of the defective part and sending an ordering request.

Resource Allocation

Limited resources like time, space, human capacity and goods are allocated through smart glasses, as the user captures distribution problems, gets informed about available capacities, or retrieves new tasks to compensate an inequitable distribution. For instance, a nurse can get the location of their colleagues displayed. This information can be used if the nurse needs help for a specific task. It may be of special relevance in case of an emergency.

Text Handling

Since many nurses, maintenance and logistics workers work in foreign countries in which other languages than their native language are spoken, smart glass applications capable of translating written text into their first language would be helpful. Moreover, such an application could be helpful for processing shippings and machine parts from other countries or translating Latin medication and body nomenclature.

Navigation

In all three domains, workers often need to navigate from one workplace to another. The optimal route can thereby depend on differing variables. For instance, nursing pathways in health care facilities can be complex. During work, nurses have to consider what needs to be brought to the patient’s room, what has to be carried away and in which order patients should be visited. Medication and hygiene essentials like towels have to be present in the patient’s room at the right time. However, these objects may be stored in different locations. A smart glass can calculate the shortest way and provide the result as a proposal to the nurse.

4.2 Towards a framework for evaluating fit of process and smart glass technology

Having identified use cases for smart glasses in logistics, maintenance and nursing, we looked for common characteristics, that make them viable for support via smart glasses. We especially looked for differentiating characteristics to existing ICT like smartphones, PCs and smart watches. Figure 1 displays our framework. Smart glass use cases are only feasible when **timely access** to information is required. If timely access to information is necessary to execute a potential use case, **mobility** requirements can make support via PC infeasible. These characteristics have already been proposed by Liang et al. for mobile technology in general [36] and therefore should also apply to smart glass use cases.

Figure 1. Framework for task-technology fit of smart glasses

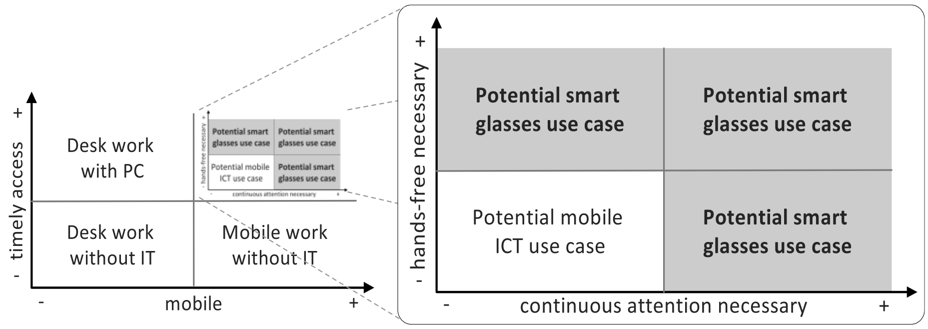

Table 4. Questions for task-technology fit evaluation

Question	*No*	*Yes*
Are both hands necessary for execution of the process?	--	++
Do the activities require timely information access?	--	++
Do the activities demand high mobility?	--	++
Is continuous attention needed?	--	++
Can in- and outputs be depicted visually and/or auditory?	-	+
Is a simple visualization possible?	-	+
Is network-connectivity possible throughout the site?	-	+
Is the amount of information needed also displayable?	-	+
Are speech-commands possible?	-	+
Is content already digitally available?	-	+
Can GPS and localization improve the process?	**o**	+
Can video-communication support the process?	**o**	+
Is the social environment open towards new technology?	-	**o**
Can technology-harmful external factors (e.g. dust) be eliminated?	-	**o**

-- prohibitive   - obstructive   **o** neutral   + favorable   ++ required

By comparing the smart glass use cases listed in the Appendix, we found that the following characteristics can help to differentiate smart glass use cases from mobile digitization use cases in general.

Digitization via smartphones and wearable devices like smart watches becomes infeasible when **continuous attention** is required or **hands-free** interaction constraints exist. For instance, it is not advisable to interact with a smartphone while operating a forklift, because the user's attention is diverted through technology interaction. On the other hand, use of smart glasses would be possible in such cases because, similar to navigation systems in cars, information is augmented in to the field of view, which allows users to keep their focus on the task at hand. Hands-free interaction constraints occur whenever a person cannot use either of his hands to interact with an ICT. Examples of such constraints are to hold an object with both hands or to perform an aseptic procedure. Smart glasses can be used under such circumstances, because applications can be designed to support interaction by voice commands.

Furthermore, we propose additional criteria for task-technology fit building upon our experiences from developing several smart glass applications with project partners. Table 4 presents the criteria as a set of questions. Using this question set, the functional scope can be further explored.

5 Conclusion

Smart glasses are an emerging technology with many potential use cases in the service sector. Their main potential lies in providing mobile information access while being able to use both hands. In this research, we have proposed a cross-domain classification framework for use cases. The framework can be used by domain experts and researchers for identification of digitization potentials in existing services and implementation of assistive systems. Our research contributes to the fields of Augmented Reality, Wearable Computing and Service Science by providing a cross-domain classification taxonomy for smart glass applications and a framework for assessing task-technology fit. Practitioners and researchers can use these artefacts to identify use cases that are of practical relevance to several domains. Our taxonomy provides a structured approach for digitization efforts of service processes. Practitioners from different service domains can identify use cases in their domain by looking at the categories and individual examples of our taxonomy. Starting from there, they can find similar digitization potentials in their domain without needing prior knowledge about smart glasses.

Once potential processes have been identified, our task-technology fit framework for smart glasses can help to assess the viability of smart glass support for a given task. Future research should empirically investigate, whether our frameworks can help practitioners identify service tasks that can be supported by smart glasses. Furthermore, throughout our research we noticed, that in all three domains data security is of central importance. Services in industry and health care often work with highly sensitive data that needs to be kept confidential. This is a complicated task, since most of the use cases we have listed imply use of cameras and networking technology. Sometimes even with external partners, such as machine suppliers or doctors. The recent advances of smart glasses technology holds promising potentials for improving service processes by providing ubiquitous access to information while working hands free.

However, the advances in smart glass technology also raise long-term impact questions. Future generations of these devices will probably have built-in cameras that are constantly recording, using computer algorithms for tracking humans and displays that only show information to its user. Diffusion of such technology into the consumer market will likely have an impact on our daily lives. Future research on privacy and ethical requirements for this pervasive technology is needed. This research may be part of a technology assessment, which allows addressing technological change as well as changes in morality. Furthermore, participative design of use cases is of high importance for being able to develop technology needs-driven. Thus, application of the framework shall imply inclusion of potential users into the discussion.

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7 Appendix

Table 5. Complete List of use cases from the domains of nursing (NU), logistics (LG) and maintenance (MT)

Use Case	Explanation	Domain(s)
	Communication Use Cases	
Streaming	Hold videoconferences from the user's perspective	NU, LG
Internal Support	*Receive process guidance from internal experts*	NU, LG
External support	*Receive process guidance from external experts*	NU, LG
Teleassistance	*Show live-stream of machine for far distance maintenance*	MT
Client communitation	*Real-time video-documentation from a user's perspective*	NU, LG
Remote Support	*Get help instructions in emergency situations*	NU
Patient Hand-off	*Display recent patient-specific information*	NU
Fire-resistant sealing	*Show modifications for external certification*	MT
	***D*ocumentation Use Cases**	
Swich infusion needle	*Reminds the nurse and documents replacement process*	NU
Digitize patient data	*Support documentation while performing health care*	NU
Patient admission	*Provide step-by-step guidance for patient admission*	NU
Measure blood sugar	*Automatically transmit data to electronic health record*	NU
Document damages	*Document damages via camera and transmit to record*	NU, LG, MT
Process execution	*Document processes from the user's perspective*	NU, LG, MT
Monitor processes	*Track processes and monitor KPIs*	LG, MT
	***P*rocess Guidance Use Cases**	
Display plans	*Show inspection plans (e.g. in multiple languages)*	LG
Display and control package	*Support of picking-process*	LG
Drug management	*Support of drug management with a result control and an overview about drugs and relevant information*	NU
Patient discharge	*Support discharge of patients via checlists*	NU
Checklists	*Support standardized processes via checklists*	NU
Step-by-step guidiance	*Provide guidance for processes or emergencies*	NU
Machine maintenance	*Instructions can be displayed and visualized*	MT
Control cabinet maintenance	*Provide step-by-step guidance*	MT
Fire detector maintenance	*Documentation of fire detector maintenance during maintenance.*	MT
Display instructions	*Instructions to deal with goods can be displayed*	NU, LG, MT
	Education Use Cases	
Support of new employees	*Onbording of new employees can be supported by step-by-step guides*	LG, NU, MT
Integration into the facility	*support integration of newcomers by placing information at locations in facilities*	NU
Transfer perspective	*Allows others to view your actions from the viewer's perspective.*	NU, MT

Use Case	Explanation	Domain(s)
	Communication Use Cases	
Machine training	*View instructions and the machines at the same time.*	MT
	Alert Use Cases	
Warnings	*Context sensitive acoustic, visual or haptic warnings and safety instructions*	LG, NU
Reminder	*Proactive or controlled notification of crucial events*	NU
	Data Visualization Use Cases	
Visualizations	*Capture information and visualize it in meetings with patients and relatives*	NU
Show optimal load	*Show parcel loading order to optimize space usage*	LG
Vital signs	*Show recently measured vital signs of patients*	NU
Show progress	*Film motions of patients and show it to them afterwards*	NU
Visualize body parts	*Improve health care treatment by visualizing body parts*	NU
Manage nutrition	*Document nutrition consumption and incompatibilities*	NU
Stacking information	*Show how to optimally stack objects*	LG
Object information	*Show additional information about the object*	LG
Show machine configuration	*Help maintenance technicians customize the maintenance to the machine at hand*	MT
Show wiring plans	*Display hands-free visualization of wiring plans next to the machine*	MT
Show patient data	*Show patient data in the patient's room*	NU
Measure objects	*Measure and document the length or size of objects*	LG
Support simulations	*Simulate real world situations for training*	NU
	Automatic Control Use Cases	
Recognize and input errors	*Input-based recognition and feedback to the user in case of errors or mistakes*	LG
Automatic monitoring	*Camera-based recognition and feedback to the user in case of errors or mistakes*	LG
Automatic monitoring for picking	*Camera- or sensor-based checking of picking, e.g. whether workers use the correct compartments*	LG
Automatic checking of promotional displays	*Camera-based checking of the assembly of promotional displays according to the specifications*	LG
Object monitoring	*Camera-based checking of damages or integrity of different objects*	LG
Automatic monitoring of dangerous goods	*Camera-based checking of the goods-handling with dangerous or hazardous goods*	LG
Checking of medication compartments	*Support examining personnel through a display of the correct compilation of medication.*	NU
Predictive Maintenance	*Data visualization on predictive actions in maintenance*	MT
	Inventory Management & Automatic Ordering Use Cases	
Automatic reordering	*The smart glass tracks consumption and re-orders material*	HC
Order parts	*Display availability of machine parts during maintenance*	MT
Material overview	*Display location and amount of existing material*	NU, LG, MT
	Resource Allocation Use Cases	
Monitoring	*Capture and analyze workflow data*	LG
Reward System	*Gamification approaches to reward efficiency*	LG
Workforce distribution	*Prioritization of tasks and workforce based on process metrics*	LG, NU, MT
Monitor workload	*Capture data and prioritize tasks and assistance based on individual performance*	LG
Use of space	*Allocate storage locations efficiently*	LG
	Text Handling Use Cases	
Translation of text	*Camera-based recognition of text followed by a translation*	HC, LG, MT
Speech-to-Text	*Enabling technology for speech-based documentation*	HC, LG, MT
	Navigation Use Cases	
Navigation instructions	*Guide employees by displaying navigation information.*	LG
Real time maps	*The smart glass displays the map with real time traffic information.*	LG
Optimize pathways	*Optimized pathways for nurses could be provided.*	NU
Find place of action	*Employees could be navigated to their workplace.*	MT

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CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities

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Abstract. Lack of proper hand hygiene is often the source of hospital acquired infections. Despite many efforts, on average, health care workers still perform hand hygiene in less than 50% of the occasions in which they must. Serious games have been used successfully to achieve behavioral change in other health care domains. In order to tackle the complex problem of hand hygiene compliance we followed a design science research approach combining the build-phase with three evaluation cycles. In this paper, we present a preliminary design of a serious game to explore the possibilities of achieving better hand hygiene compliance of health care workers.

Keywords: hand hygiene, Serious Games, Augmented Reality, health care

1 Introduction

Healthcare associated infections (HAIs) are infections for which there is no evidence of presence or incubation at the time of admission. Patients with a HAI need longer to recover and have an increased probability to die. In the European Union alone, the estimated number of HAIs is 4.5 million annually, leading directly to around 37.000 deaths, 16 million extra days of hospital stay and 110.000 indirect deaths [7, 14]. The most effective counteractive measure to HAIs remains proper hand hygiene by health care workers [1]. It is estimated, that 20-30% of HAIs could be prevented by better hand hygiene compliance [7, 14].

The problem of hand hygiene in hospitals is a complex issue with two main aspects: (1) proper training in the cleaning technique and (2) compliance with desinfection procedures [15]. In recent years several applications to improve education of the hand cleaning technique have been implemented and tested in the field [10]. However, since health care workers wash their hands in less than 50% of the appropriate moments [23], the main issue is behavioral. Therefore, it is of interest to explore new approaches of improving health care workers' hand hygiene behavior. Thompson, Debbe, et al. found that theoretically based serious games can be effective at achieving behavioral change in both diet and physical activity [13].

In this paper, we describe the design of a serious game for the Microsoft HoloLens with the purpose of improving hand hygiene compliance. We have built a first prototype of an Augmented Reality application named CatCare. We decided to use Augmented Reality in order to make the users relate their actions and the lesson of the game to the real world and thus have implemented the application on the Microsoft HoloLens. The Hololens is capable of markerless tracking and therefore does not require a set up procedure before users can play with it. In CatCare, the user needs to take care of sick cats by feeding them. Whenever the user touches a cat, his hands become visibly contaminated and he needs to wash them before touching another cat. If the user fails to do proper hand hygiene, other cats will get infected and the user looses the game. The application is still research in progress. However, three implementation iterations with evaluations have already been conducted. We contribute to the field of serious games and gamification for health care education by presenting design objectives gathered from the scientific literature and learnings that have emerged throughout the development of the application.

2 Research method

In order to design a serious game to educate and motivate health care workers, patients and visitors in health care facilities, our research applies the design science research method (DSRM) [22]. We follow the methodological steps described by Peffers [22] involving the following activities: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design and development, (4) demonstration, (5) evaluation and (6) communication. In this article, we apply this methodology as follows: In the introduction section we motivate (1) the problem of hand hygiene compliance and define the central solution objective of the artifact. After reviewing the literature associated with the problem, we derive requirements for the artifact (2). Based on the background literature we develop an artifact iteratively (3). We demonstrate (4) the artifact's evolution and the design knowledge that was gained through iterative testing. The artifact was evaluated (5) in several stages of its evolution via questionaires and interviews. This article fulfills the purpose of communicating the results (6).

3 Related work

CatCare was implemented with WHO five moments as educational basis. The WHO five moments is a simple conceptual framework for when hand hygiene should be performed is are used as the basis for professional medical education [9].

Researchers have drawn upon psychological theory to explain the lack of hand hygiene compliance. Kretzer & Larson [4] found that beliefs, perceived health threat, cues, self-efficacy and attitude influence hand hygiene behavior. In order to increase health care worker's perceived threat we used Augmented Reality so the user sees virtual germs on his hands and surroundings.

Kretzer & Larson [4] also found consistent evidence, that self-efficacy is associated with behavioral change and that interventions targeting behavioral change should include the concept of self-efficacy [4]. Self-efficiacy can be influenced in various ways. In the past serious games have been used to increase self-efficiacy in various health care domains [13, 12, 11], such as diabetis and HIV prevention.

In recent years researchers have started to use gamification and serious games as interventions to improve hand hygiene compliance. Sanchez et al. [8] did a literature review on gamification but only identified four games related to hand hygiene.

Vazquez et al. [16] built a simulation, where users have to decide when and how they must perform hand hygiene. However, their simulation does not simulate a stressful situation as health care professionals experience throughout their daily routine. Marques et al. [18] used a gamification approach in a health care facility. Their system tracks the nurses' actions and awards points for good hand hygiene behavior but does not focus on facilitating the education of health care workers.

Galluzi et al. and Kutafina et al. [17, 10] focus on teaching proper hand washing technique via gamification but do not teach in which situations hand hygiene is necessary.

3.1 Design objectives based on the literature

The factors that lead to poor hand hygiene compliance of individual health care workers have been researched extensively. Risk factors for hand hygiene compliance include understaffing, bad role models and working in an intensive care unit. Moreover, male health care workers and physicians are more likely to have low hand hygiene adherance (compared to nurses) [1, 7].

Many studies highlight that education is a cornerstone for improvement with handhygiene practices but there are limitations such as financial constraints or lack of teaching experience [1, 7]. Moreover, education has been found to be most effective, when it includes workshops, bedside teaching, and simulation-based training [7]. Therefore, in order to create a simulation that resembles the real world struggle in which health care workers need to do proper hand hygiene while having to treat many patients, we propose that the artifact should simulate a stressful activity that needs to be accomplished, while the user needs to perform proper hand hygiene.

Additionally, the artifact should be easily accessible to health care workers. it should not require prior knowledge, complicated setup procedures or a special infrastructure. Moreover, it should be easy to fit into the time schedule of health care workers. From this reasoning we argue that the artifact should be easily accessible to health care workers.

Furthermore, high-quality and timely feedback on hand hygiene behavior is important to raise the awareness of health care workers [7, 5]. Being caught red handed makes it easier for people to remember their actions that lead to the mistake. Moreover, if nobody sees the mistake and judges, it might be more likely to achieve a mindshift and behavioral change. Therefore the user should get instant feedback when he does a severe hygiene mistake.

4 Artifact Design

To study hand hygiene compliance in a serious game context, we developed CatCare. Since it was developed iteratively some parts of it have changed over time. We will now briefly describe the latest version (version 3) of CatCare:

Figure 1 shows an overview of the holograms the user sees augmented in to his surroundings while playing CatCare. On the far right of the figure is the sink. The two beds with the sick cats are to the left of the sink. The food bowl is on the counter with the green symbol on the left and the water bowl is on the counter with the blue water drop. There are five cats wandering around on each bed. The cats on one bed have a different disease than the cats on the other bed and need to be held in quarantine from each other. The user can see that the cats are sick by coloured particles radiating around the cats. The cats on the first bed have green particles and the cats on the other bed have red particles. Over time a cat will become thirsty or hungry. The user then needs to pick up the cat and carry it to the food or the water bowl. Once the cat is done with eating or drinking, the user needs to carry it back to its bed. If the cats are not nurished within a certain period of time, they will starve and the game is over. Whenever the user picks up a cat, his virtual hands will get contaminated with the cat's disease. The virtual hand will then also have radiating color particles around it. The user can decontaminate his hands by clicking on the virtual sink. The virtual hands will then instantly become clean again. If the user transmits a disease to a kitten it dies and the game is over. Therefore, in order to win the game, the user needs to make sure the cats get their food in time, while he does proper hand hygiene in order to prevent transmitting a desease. So far, three iterations of the game have been implemented. Each iteration was evaluated using the System Usabilty Scale (SUS) and open questions for feedback. The first iteration was tested by 39 users and had a SUS of 71.5, the second iteration by 9 users (SUS: 74.1) and the third iteration by 14 users (SUS: 73.9)

Next we will discuss the differences between the three iterations of CatCare, why they were made and what conclusions we derived from them.

5 Discussion

Regarding existing design principles, there is a consensus in the scientific literature on serious gaming and gamification that games need to be fun for the user [21]. However, the use of gamification and serious game design principles in mHealth applications is yet a burgeoning innovations practice [20]. In order to make our application fun to use, we tested different game elements and regularly tested the usability of our application. To make design decisions we relied on observations, verbal comments from the users, results of the SUS and written comments in the open ended comment section we added to the SUS.

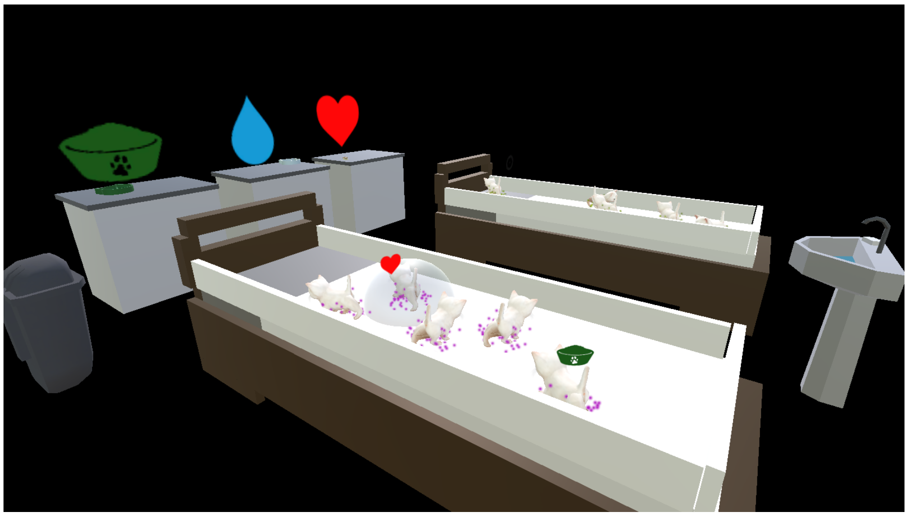

Fig. 1. This figure shows an overview of the holograms the user will see augmented in to his surroundings.

In version 1 we were using a virtual arrow to help the user learn the game. The arrow followed the naive strategy depicted in figure 2 without optimizations. However, during test we soon observed that users were ignoring the arrow and only started using it once we told them to use it. Moreover, they would then just click on whatever the arrow was pointing at without reflecting upon their actions. In version 2 we therefore read them written instructions explaining the setup and the goals of the game without using the arrow. Users then found optimizations to the naive strategy much faster and also seemed much more engaged in the game.

In versions 1 & 2 there was only one level and users often found that the game was not challenging enough. Two users wrote they would have liked "more difficulty, more variation" and "more complexity". Therefore, in version 3 we implemented four different levels so the users could adjust the difficulty to their preferences. Figure 2 shows a flow diagram of the game and table 1 shows an overview of the different levels of CatCare. When we tested the application with users we found that users seemed more engaged and tried out different levels, until they found a level that was appropriately challenging for them.

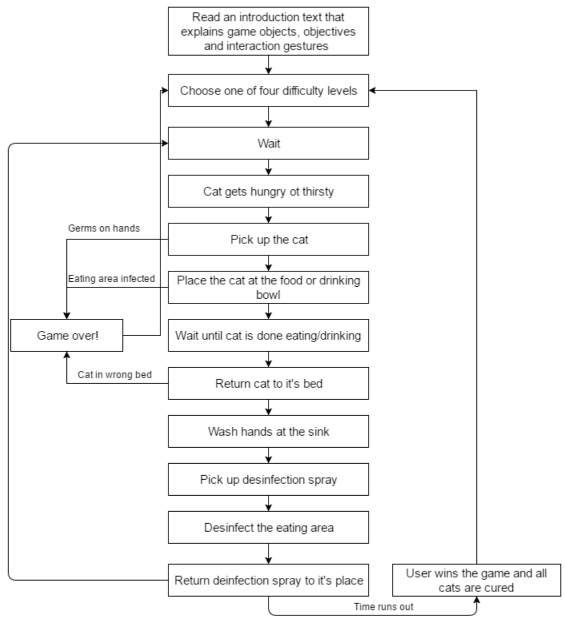

Fig. 2. This figure shows a flowchart of the CatCare application

6 Evaluation

There is no standard for measuring compliance with hand hygiene practices. [19] The three most frequently reported methods of measuring compliance are direct observation of practice, self-report of healthcare workers and indirect calculation based on hand hygiene product usage or electronic monitoring devices [19].

We are planning to evaluate CatCare with health care workers in a health care facility. We will let each health care worker in a ward play CatCare for half an hour following a standardized procedure. The treatment will be repeated every two weeks. Over the course of the intervention and the three succeeding months we will measure the desinfection fluid consumption in the ward and a second ward that we will treat as the control group. Consumption of hand-rub desinfection fluid is an accepted dependant variable of hand hygiene compliance [1].

7 Conclusion and potential contribution

Lack of hand hygiene compliance in health care facilities is a serious problem. Serious games have been used in other health care domains to achieve behavioral change. In this paper, we utilize a design science approach to design, develop and evaluate our serious game artifact. We are developing an Augmented Reality serious game called CatCare that could be used for health care worker's hand

Table 1. Differences between the levels

Level 1 (easy): One cat will randomly get thirsty every 40 seconds and the user has 40 seconds time to give water to the cat before it dies.
Level 2 (medium): Cats can get hungry or thirsty. One cat will randomly get hungry or thirsty every 30 seconds. Cats die if the user does not treat them within 30 seconds
Level 3 (hard): Hunger or thirst will appear every 20 seconds. Cats die if the user does not treat them within 30 seconds
Level 4 (extreme): Hunger or thirst will appear every 15 seconds and the germs become invisible. Cats die if the user does not treat them within 30 seconds

hygiene education. The novelty of our approach lies in the idea to employ a serious game that has parallels to health care workers daily routine. By using Augmented Reality, we enable the users of CatCare to see where germs are and how they are transmitted on to health care worker's hands. By focusing the user's attention to tending cats, we simulate the time pressure and stress that health care workers perceive in their everyday life and diverts them from doing proper hand hygiene. Since CatCare provides instant feedback when hand hygiene errors are made, users can test methods for themselves that will help them perform proper hand hygiene under stress.

We have described how we are planning to evaluate the application. If we can show that the application improves hand hygiene behavior of health care workers, the application could be used as a tool in the education of health care workers. Maybe it could also be used in regular intervals to refresh the hand hygiene motivation and knowledge of health care workers. If we can show that people without prior knowledge of hand hygiene can learn hand hygiene from the artifact, it could be used to make hospital visitors aware of HAIs.

Our work contributes to the literature on hand hygiene compliance by exploring a new design-oriented intervention. Finally, we contribute to the field of health care education by presenting design objectives for serious games derived from the scientific literature and learnings from implementing them into an artifact.

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Development of a Smart Glass Application for Wound Management

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Abstract. Treatment of chronic wounds is a challenging task for health care professionals. When treating chronic wounds, accurate documentation of wound development via photos, measurements, and written descriptions are crucial for monitoring the healing progress over time and choosing the right wound treatment. Currently, however, wound documentation is often perceived as inaccurate and incomplete. In this research, we follow a user-centered design science approach to develop a smart glass-based wound documentation system to support healthcare workers. Through ethnographic fieldwork, interviews and prototype tests with focus groups, we find that smart glass applications hold potential for improving the wound documentation process because they allow for hands-free documentation at the point of care.

Keywords: Augmented Reality, Health Care, Wound Management, Design Science, Smart Glasses

1 Introduction

As more and more time in healthcare is being spent on administrative tasks, there is less time for direct patient care [1]. Using smart devices to provide information access for service processes at the point of care (POC) is therefore a promising endeavor to improve outcomes and reduce administrative burdens [2].

Within our research, we focus on wound management, as an exemplary service process within health care. Treatment of chronic wounds is a challenging task in health care [3]. In Germany, annually, 2-3 million patients receive wound treatment. Among those, about 900000 suffer from chronic wounds [4]. When treating chronic wounds, accurate documentation of the wound development via photos, measurements, and written descriptions are crucial for monitoring the healing progress over time [5]. Currently, health care facilities often employ digital cameras and hand-written documentation, which are cumbersome and time-consuming to use [6]. Moreover, the documentation often does not meet quality standards.

Augmented Reality (AR) smart glasses, such as the Microsoft HoloLens, are a new generation of smart devices that have the potential to transform healthcare processes and healthcare management in general [7, 8]. Their main advantage is that they can be operated hands-free, thus allowing healthcare workers to use both hands for their work while having access to an information system [9].

Despite their potential, research on the usage of smart glasses in the service sector is still at a very early stage. In order to build an artifact that supports the wound management process, we follow the Design Science Research (DSR) guidelines proposed by Hevner et al. to iteratively develop smart glass applications and evaluate them with health care professionals [10].

2 Research Approach

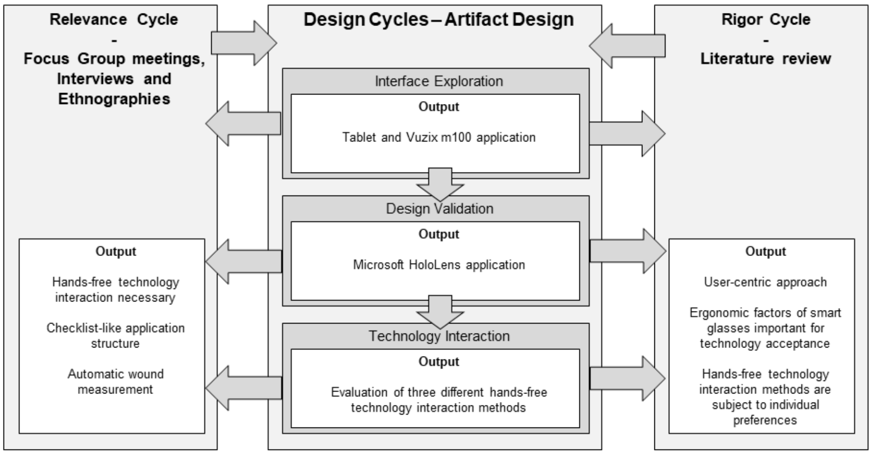

Figure 1: Graphical depiction of the research approach

The aim of our research is to improve digital support for the wound management process in the health care sector using a design science approach. Throughout our research, we followed the guidelines for Design Science Research (DSR) as described by Hevner [10]. The DSR approach consists of relevance, rigor and design cycles. The rigor cycle provides past knowledge to the research project and ensures that the designs produced are research contributions [10, 11]. The design cycle is the heart of any design science research project [10]. This cycle of research activities iterates more rapidly between the construction of an artifact, its evaluation, and subsequent feedback to refine the design further [10]. Finally, the relevance cycle typically initiates DSR with an application context that not only provides the requirements for the research as inputs but also defines acceptance criteria for the ultimate evaluation of the research results [10].
Figure 1 depicts how relevance, rigor, and design cycles were employed in our research. As suggested by Hevner, we started with a relevance cycle by discussing challenges of the current wound management process with healthcare professionals in focus group meetings and by shadowing them during their daily activities [10]. Thereafter, we conducted a rigor cycle by reviewing the scientific literature on wound management, technology acceptance, and smart glasses. Building upon this, we conducted three design cycles. In each design cycle, we built and tested prototypes in order to gain insights into how process support for wound documentation should be designed in order to improve

the workflow of the wound managers. Each of the cycles is described in more detail in the following sections.

3 Related Work (Rigor Cycle)

In order to accomplish our objectives and to help understand the potential likelihood of success of different technology designs being considered, we turned to three major streams of research that we felt could inform our thinking: (1) Technology Adoption (2) Wound Management and (3) Augmented Reality smart glasses. First, we review the literature on Technology Adoption and employee satisfaction in order to understand the factors that are crucial for the adoption of wound documentation artifacts in health care settings. Next, we turn to the literature on Augmented Reality and 3D User interfaces and discuss their relevance to our work. Finally, we discuss the characteristics of the wound documentation process that have been discussed in scientific literature.

3.1 Technology acceptance and employee satisfaction

Many models and theories for technology acceptance have been adopted from sociology and psychology and tested over the last decades [12]. The best-known ones are the Technology Acceptance Model, the Unified Theory of Acceptance and Use of Technology (UTAUT) [12]. In our research, we decided to use UTAUT, because it was originally developed to explain the technology acceptance and use behavior of employees [13]. UTAUT has been used before in several instances to predict define and enhance use [14]. The UTAUT questionnaire measures factors like performance expectancy, effort expectancy and social influence of individuals to use an artifact. These constructs predict an individual’s intention to use the artifact, which in turn predicts actual use.

Satisfaction refers to the perceived discrepancy between prior expectation and perceived performance after consumption – when performance differs from expectation, dissatisfaction occurs [15]. The service profit chain directly links employee satisfaction to customer satisfaction [16]. Increasing employee satisfaction is therefore likely to improve overall service quality.

3.2 Wound Management

Chronic wounds pose a major problem in healthcare. Annually 2-3 million German patients need wound treatment, of which approximately 900000 patients suffer from chronic wounds, which is defined by a treatment period of more than eight weeks [4].

For the treating physician, it is obligatory to provide accurate documentation of the wound process [5]. The documentation is not only required by German law but also serves as a basis for care quality assessment [5]. Yet, there is a lack of clear direction and agreement on what tools to use for wound documentation [17].

The documentation improves wound treatment outcomes because it enables healthcare professionals to assess how the wound has changed over time and relations between interventions and outcomes become evident [17]. This enables professional therapy planning and ensures the best possible care for the patient. Moreover, standardized wound treatment documentation helps to shift from practice- to evidence-based wound treatment [18].

The current wound documentation process is complicated to execute for nursing staff and can lead to serious problems. These include the transmission of germs. This can happen via the surfaces of digital cameras or similar devices, which are used for image capture of wounds [6]. Nurses may touch devices numerous times during the day without washing their hands, potentially spreading germs to others [19].

Moreover, the actual recording of the photograph is challenging for the nursing staff. Often, several nurses are required for such documentation, which makes it a time-consuming endeavor and adds to their workload. For hygienic reasons, the documentation is typically written in the station room after the wound treatment is completed and is therefore not done in a timely manner [17]. This requires nurses to remember specific details about the wound until they reach the station room. The resulting wound documentation is often described as inaccurate [17, 18].

Many POC documentation systems, such as Physician-order entry systems or smartphone and tablet applications have been tested in the context of wound management [20]. However, POC systems whose functionality mismatches the workflow are not valued by healthcare workers [20]. A reoccurring problem with existing POC systems is that healthcare workers cannot use them when they do not have their hands free or need to perform aseptic procedures [21]. Smartphones and laptops are not well suited for documentation at the POC, because they should not be touched while the practitioner's hands are sterile or soiled. In contrast to hand-held devices, smart glass applications can be used hands-free. Information is displayed in the user's field of view and technology interaction can be done through hands-free interaction modalities such as voice commands or eye blinking.

3.3 Requirements for Smart Glasses in Health Care

Some smart glasses make use of Augmented Reality (AR) while others just display information that resides statically in front of the user's eyes. The goal of AR is to bring additional information as seamlessly as possible into the view of a user [22]. This is done by adding real-time interactive virtual three-dimensional (3D) elements into the user's real-world environment [23]. AR smart glasses have been tested in various service-related contexts. For instance, they have been used for collaboration scenarios, minimal-invasive surgery, displaying assembly instructions or supporting workers to pick the right parts from a shelf in logistics [24].

Irrespective of whether a smart glass uses AR or not, users need to be able to interact with their smart glass. Since such devices are typically operated in mobile and 3D-environments, established interaction paradigms such as keyboard, mouse or the Windows Icons Menus Pointers (WIMP) are not a good fit for this technology [25]. Instead, physical 3D-interaction concepts like gestures, hand pointing, ray-casting with hand-held devices, eye blinking, gazing or audio-based interaction concepts like speech commands or natural language processing can be used [26, 27].

Several of these modalities have been discussed for septic-safe contexts [28]. Septic-safe technology interaction needs to occur without touching the device [28–31]. During surgery, there may occur numerous scenarios over which a physician could be cut off from the availability of individual modalities for technology interaction. Surgeons could have their throat indisposed generally or momentarily, preventing the use of voice commands. Moreover, surgeons also often have both of their hands involved during the operation, so a technology interaction system based on hand gestures should not be used as a base interface [28].

Several of the design principles for smart glasses in the scientific literature focus on improved social acceptability. Instead of designing all-purpose smart glasses, smart glass designs should rather focus on clear, task-oriented usage to allow users to see them as a dedicated aid in a specific work environment [31]. In addition, knowledge about the intended use of smart glasses and about the actions performed with the device is crucial when it comes to user acceptance since it helps to reduce objections [31].

Apart from paying attention to social acceptability, it is also crucial to focus on user experience when designing wearable healthcare systems [32]. A wearable health system should be lightweight, easy-to-use, secure, effective, reliable, low power consuming, scalable, cost-efficient, of embedded intelligence, and able to keep a connection with a remote medical station [32]. Moreover, a bad performance can also trigger negative usability perceptions. Sultan et al. suggest that application reaction times should not exceed two seconds [33].

Requirement	**Description**
LRQ1: Hands-free interaction	Interaction needs to occur without touching the device [28–31]
LRQ2: Multi-modal interaction	Some interaction modalities might not be available [28]
LRQ3: Task orientation	Task orientation can improve technology acceptance [31]
LRQ4: Wearability	Lightweight, comfortable and noninvasive [32]
LRQ5: Interactivity	Minimalistic, intuitive interface for low cognitive effort [32]
LRQ6: Security	Secure authentication and data storage [30, 32]
LRQ7: Effectiveness	The system should perform well and robust under all circumstances [32, 33]
LRQ8: Low power consumption	Efficient algorithms extend battery life [28, 32]
LRQ9: System Validation	New systems should be compared to existing procedures [32]

Table 1: Requirements for hands-free interaction derived from the scientific literature

4 Relevance cycle

To design an application for a specific use case, it is essential to first analyze the underlying process in detail. This allows the best possible understanding of the current application domain, any limitations, user needs, or general problems. Based on this, requirements can be determined which are to be met by the implemented application. A triangulation of ethnographic research, expert interviews and focus group meetings was used in collaboration with several nursing homes and hospitals to gain an initial understanding of the health care domain and the wound management process. More details on the triangulation approach and its results are described below.

4.1 Research procedure

Ethnographic studies were carried out in one hospital (40 hours total) and in two nursing homes (60 hours each) in Germany. In some health care facilities wound management is delegated to dedicated wound management experts, while in other facilities wound management is integrated into the daily routine of the staff of a ward. Throughout the ethnographic studies, we had the opportunity to watch 14 different health care workers throughout their daily work.

In two cases, health care workers specializing in wound care were accompanied during their daily work. The other 12 health care workers were followed as part of multi-day internships in health facilities. Since our studies took place in facilities run by different health care providers, different types of documentation processes could be observed. Observations were captured in field notes for later analysis. In addition, 8 formal and various informal interviews were conducted with wound experts and other members of the staff.

The questions for the formal interviews were pre-formulated in a semi-structured interview guide and served as a basis for discussion during the interviews. Building upon these insights a focus group meeting was conducted in order to discuss the results and to get input for a concept of a first prototype. The goal of the relevance cycle was a detailed understanding of the current process of wound documentation as well as the associated requirements for the application to be developed. Table 1 and 2 provide an overview of the interview partners and facilities in which the ethnographic studies were conducted.

4.2 Results of the relevance cycle

Although the general process is similar in most facilities, in practice, the wound documentation process often differs in some details among facilities managed by different care providers. Moreover, information system support of the process was very heterogeneous. While in some facilities, the patient's wound data was recorded with paper files, other facilities use special software.

The ethnographies showed that the wound documentation is divided into two parts: Initial and continuous documentation. Initial documentation is done only once, when a wound is first detected and includes data such as the location of the wound and the reason it occurred. The continuous documentation is conducted repeatedly at regular time intervals and includes measurements of several wound parameters (e.g., length, width and color of the wound). The documentation is performed in a very structured manner and is often based on checklists. The interval at which patients' wounds are documented should not exceed one week and occur additionally whenever bandages are changed or when significant changes to the wound are noticed. A typical sequence of steps for continuous wound documentation is shown in Figure 2. The orange-marked blocks indicate process steps which experts consider to have the potential for digital support.

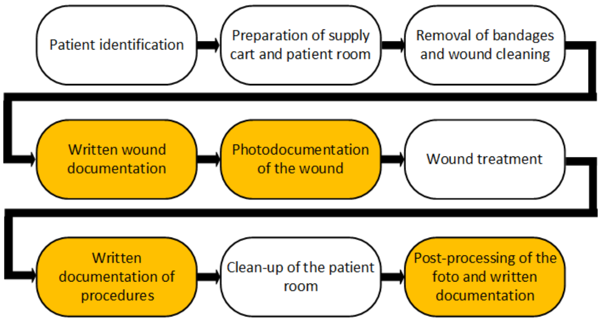

Figure 2: Overview of the wound management process

4.3 Discussion

Requirements	Description
FRQ1: Photo functionality	It should be possible to take pictures of wounds
FRQ2: Hands-free documentation	Both hands are needed for stabilizing the patient during continuous documentation
FRQ3: Low cognitive effort	It should be possible to communicate with the patient while documenting
FRQ4: Easy to learn and to use	The application should support the process without making it more complicated
FRQ5: Language Barrier	Voice commands should work for users with accents
FRQ6: Compliance with regulations	Wound documentation should be complete and accurate

Table 2: Requirements for hands-free interaction derived from field research

During the focus group meeting and the interviews, several requirements for a digital wound management solution were discussed. The results are summarized in Table 2. Experts confirmed that hands-free interaction is necessary for documentation at the POC and emphasized that they often need both hands to stabilize the patient during wound treatment. One especially challenging part of the documentation process is to take pictures of the wound while stabilizing the patient. Wound managers would thus welcome an artifact that can take pictures of the wound while they stabilize the patient with both hands. Wound treatment can be painful for the patient. In order to divert attention from pain and to create a trusting atmosphere, wound managers often engage in conversations with the patient while they treat the wound. In order to enable conversations with the patient, a digital wound management application should thus demand as little cognitive effort as possible. Quite a lot of healthcare workers in Germany have migrated from other countries and speak with an accent. If hands-free technology interaction is implemented using voice commands it is important that it also works robustly for non-native speakers. Finally, wound documentation is currently often filled in incompletely or inaccurately. Documenting at the POC and making all input fields mandatory were seen as a potential solution to improve documentation outcomes.

5 Artifact Design (Design Cycle)

The technology acceptance literature and our insights from the relevance cycle suggest that usefulness and ease of use are important prerequisites for acceptance of a digital wound management application. Therefore we decided to focus on designing a digital solution that improves the workflow of wound managers. We followed a user-centered approach by building upon the design requirements identified in the rigor and relevance cycle.

5.1 First Design Cycle – Interface exploration

In this first design cycle, we were especially focusing on the challenge of finding a balance between usability and hands-free use. While interaction paradigms for tablets, smartphones, and PCs are well established and known to the general public, hands-free interaction modalities such as voice commands and hand gestures are known to a lesser extent. While selecting among a limited set of options works robustly for hands-free modalities like voice commands, more complex tasks such as filling free text input fields are complicated and error-prone.

Suggestion and Development

We decided to tackle this challenge by using a combination of devices. The initial part of the wound documentation was implemented on a tablet device. The interaction paradigms of tablets and smartphones are well known to most health care workers and it is easier to type names and select wound locations on such an interface. Since the initial documentation only needs to be done once and could be performed in the patient room before hands are disinfected, this seemed to be a rational approach.

The continuous part of the documentation can be implemented using predefined selection options. Users are not required to insert free-text input. Therefore we implemented the continuous part of the documentation as a hands-free application on a Vuzix m100 smart glass. The Vuzix m100 is a monocular smart glass that displays visual

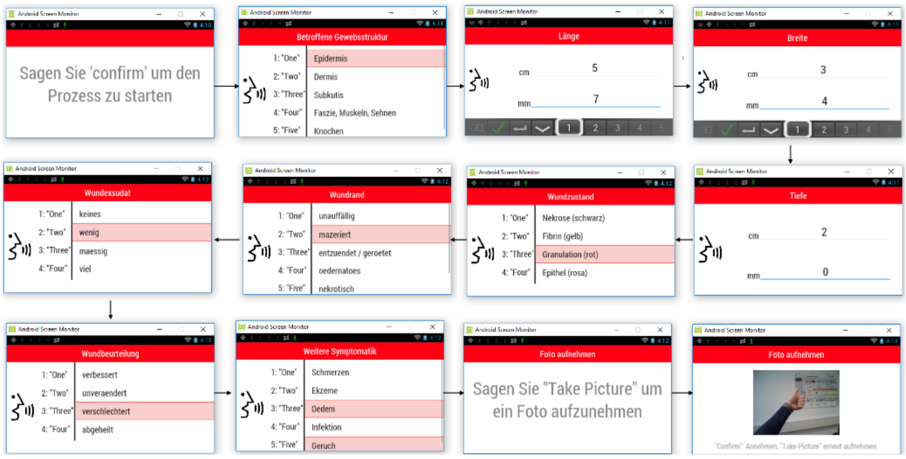

Figure 3: Overview of the sequence of screens in the Vuzix m100 application

information via a little prism that is placed in front of one eye. A checklist-like structure was used to guide users through the wound documentation process. Figure 3 shows an overview of the sequence of screens.

Evaluation

The application was tested with the focus group that had already been consulted in the relevance cycle. It consisted of 8 wound management experts. The experts had the opportunity to try out the prototype application extensively and give feedback. Several practice runs were conducted using a dummy doll. Overall, the approach of using a combination of tablet and smart glass application was well received. Using voice commands to interact with the smart glass worked robustly, even for non-native speakers, and the experts made positive remarks about the simplicity and usability of the application. The sequential checklist-like structure of the application allowed them to focus on one aspect of the documentation at a time inducing only very little cognitive load.

While the experts were not concerned that the application might induce high levels of cognitive load they were unsure how patients would react to them speaking voice commands. Moreover, the ergonomics of the Vuzix m100 were criticized. The one-sided weight distribution and unstable design prevent the display remaining rigidly in place. This requires the user to touch the prism and put it back to the right place whenever the head is tilted, which is not possible after hands have been disinfected. Moreover, experts that normally would wear eyeglasses had difficulties reading the display because they were not able to wear their normal glasses together with the Vuzix m100.

Finally, the experts wished that the smart glass had a function that would help them measure the size of the wound without having to use their hands. In the current process, paper rulers are used for this purpose. The experts explained that it is difficult to hold the paper rulers in place while taking a picture of the wound. In addition, the use of a ruler carries the risk of transmitting germs into the wound and is difficult to handle while stabilizing a patient.

Discussion

While the overall concept of splitting up the documentation to a tablet and a smart glass for balancing usability with hands-free capabilities was supported, several new requirements were discovered throughout the evaluation. They are summarized in Table 3.

Requirements	**Description**
RRQ1: Ergonomics	Smart glasses need to remain in place rigidly
RRQ2: Usable with normal eyeglasses	It should be possible to wear normal eyeglasses together with a smart glass
RRQ3: Automatic wound measurement	A software feature that measures the length and width of the wound would be very helpful
RRQ4: Alternative to voice commands	Voice commands are good for hands-free use but there should be an alternative modality in case a patient feels uncomfortable with it.

Table 3: Refined requirements for a digital wound management application

5.2 Second Design Cycle – Design Validation

Building upon the insights of the first design cycle we tested new smart glass designs with improved ergonomics and looked into ways how an automatic wound measurement feature could be implemented. While previous work indicates that gesture-based interaction is not a good solution for surgeons [32], we wanted to test whether this also holds for the process of wound management.

Suggestion and Development

The Microsoft HoloLens is a smart glass that weighs considerably more than the Vuzix m100 but remains in a rigid position on the head and allows users to wear their normal eyeglasses. It provides built-in gesture-based interaction and voice commands that work robustly. Moreover, it has built-in depth sensing capabilities that make it possible to measure the size of a wound.

We replicated the continuous wound documentation application designed for the Vuzix m100 on the Microsoft HoloLens (see Figure 3). Moreover, we implemented a

Figure 4: Wound measurement feature form the user's perspective

wound measurement feature, which allows the user to measure the length and width of a wound without a paper ruler. The picture on the right side of figure 4 shows a nurse wearing the Microsoft HoloLens. The picture on the left shows how the wound measurement feature looks like from the user's perspective.

Evaluation

We tested the application with the same expert focus group that had been consulted in the first design cycle. Additionally, we evaluated it in a workshop with five wound management experts from a different care provider. The experts liked the measurement function and the possibility to complete the entire process in the patient's room without having to use their hands. They found the ergonomics of the Microsoft HoloLens to be much better suited for their purposes. Despite weighing significantly more than the Vuzix m100, the HoloLens is more comfortable to use, because the weight is well-balanced and it remains rigidly attached to the head even when the head is tilted. Moreover, it is possible to wear normal eyeglasses together with the HoloLens which makes it easier to read the displayed information.

The experts were skeptical that the gesture-based approach would be feasible in practice for two reasons. First of all, they found it tiring to hold one arm outstretched for prolonged periods of time. Second, they preferred to have both hands available for treating the patient. While experts liked the usability of the audio based technology interaction via voice commands they repeated their concerns that some patients might not accept it. They wished for a technology interaction modality that allows them to use smart glasses while working hands-free without having to use audio-based technology interaction.

Discussion

Overall, the wound management application was well received and the requirements pertaining to ergonomics and hands-free wound documentation could be addressed with the Microsoft HoloLens. However, gesture-based technology interaction was not seen as a viable solution to complement voice commands.

5.3 Third Design Cycle – Technology Interaction

The overall structure and design of the artifact had been confirmed in the evaluations of the first two design cycles. However, technology interaction using only voice commands was not considered appropriate in every situation. Moreover, the application had so far only been evaluated in group settings. This is a weakness because participants of the evaluations might have been reluctant to voice criticism openly. Therefore we decided to focus on testing alternative technology interaction methods and to validate the overall system design in an experimental setting with individual users to assess health care worker's willingness to use the developed artifact.

Suggestion and Development

The 3D user interface literature proposes quite a few methods for technology interaction. However, many of them are not fit for the hands-free context of wound management (e.g. hand gestures and hand-held devices). Foot pedals have been used for technology interaction in operation rooms, but are not useful for wound management, because foot pedals would have to be present in every patient room [21]. We decided to test whether eye blinking is an appropriate technology interaction method. This method does not interfere with the wound manager's work and is not likely to disturb patients. Moreover, research suggests that eye blinks can be detected reliably by inwards facing cameras in smart glasses [34].

The Microsoft HoloLens does not have inward facing cameras, but future generations of smart glasses are likely to make use of them for eye calibration [34]. In order to test whether eye blinking is a promising modality for technology interaction in hands-free contexts, we decided to employ a Wizard-of-Oz approach [35]. Throughout the evaluation, a trial manager would watch the participant's eyes and clicked on a Bluetooth device whenever the participant blinked twice with both eyes.

Evaluation

We tested voice commands and eye blinking as technology interaction methods in a within-subject experiment with healthcare workers. We recruited 45 healthcare workers with wound management experience at four hospitals, three ambulant and two stationary healthcare providers. The sample comprised 33 women (73.3%) and 12 men

(26.6%). The average age of the nurses was 40.48 years (standard deviation (SD) = 12.03) and they had 16.20 years of experience on average (SD = 11.63).
Overall, a total of two manipulated scenarios and one baseline scenario were presented to subjects: (1) the wound documentation process currently in use at the healthcare facility; (2) The HoloLens application using voice commands and (3) the HoloLens application using eye blinking.

The experiment was conducted in quiet rooms at the healthcare facilities. In each of the experimental treatments, participants were asked to document different wounds that we had printed on paper using the experimental documentation artifact.

Data was collected using a closed online questionnaire. It contained questions on: Demographic Data, Performance Expectancy (4 items), Effort Expectancy (4 items), Patient Influence (2 items), Behavioral Intention (3 items), nurses' satisfaction (4 items) and open comment sections after each treatment. Participants needed about 5 minutes on average to fill out one part of the questionnaire. Participants were asked to fill out one part of the questionnaire after each treatment. Moreover, the time needed to complete a treatment was taken for later analysis.

Results

Outcomes	(1) Current process		(2) Voice commands		(3) Eye blinking		Comparison
	M	SD	M	SD	M	SD	
Performance Expectancy	4.33	1.33	4.94	1.55	5.47	1.42	3>1***, 2>1*,
Effort Expectancy	5.08	1.15	5.34	1.42	5.74	1.24	3>1**
Patient Influence	4.76	1.34	4.52	1.65	5.08	1.41	No significant effects
Behavioral Intention	4.15	1.59	4.87	1.50	5.19	1.44	3>1**, 2>1*
Satisfaction	3.89	1.58	5.09	1.42	5.63	1.27	3>1***, 2>1***, 3>2*
Completion times	NA	NA	124.66	90.02	85.94	32.59	3>2***

Table 4: Experiment results (p-value significance level: *.05, **.01, ***.001). Completion times are reported in seconds, while all other variables are 7-point Likert scales.

Data associated with technology acceptance and satisfaction outcomes were analyzed with a repeated-measure ANOVA test with three within-subject factors as independent variables: The tool wound managers are using in their current process (1), voice commands (2) and eye blinking (3) using the wound management application on the HoloLens. To test differences between the treatments contrast tests, based on the Wilcoxon signed-rank test were used [36]. All significant results ($p < .05$) of the contrast tests are reported in the "Comparison"-column of Table 4. In addition, Table 4 also reports means, variances and completion times. Due to problems with the logging system on the HoloLens only n = 33 datasets could be used for the evaluation of the completion times. In addition, the completion times of the current process were not measured during the experiment.

6 Conclusion and Outlook

This research makes several contributions. First, we present design recommendations for wound documentation systems. We find that such systems need to be usable hands-free and documentation needs to take place at the POC. Health care workers need to stabilize and interact with the patient while measuring the wound's size and taking a photo of it.

These restrictions imply that the usage of smart glasses is a good fit for the task. Smart glasses can be used hands-free and it can be used in mobile contexts. Using a Design Science Research approach we iteratively developed a smart glass and tablet application that helps wound managers to document wounds. Furthermore, we test eye blinking, voice commands and hand gestures for hands-free interaction with smart glasses. We find that voice commands and eye blinking yielded more favorable technology acceptance outcomes than the documentation systems currently in place in health care facilities. Moreover, participants were significantly faster using eye blinking compared to voice commands.

Future research could build upon the presented design recommendations to digitize further processes in the health care sector. Moreover, digital support using hands-free technology interaction with smart glasses could also be used for processes in other fields, such as machine maintenance or customer service. Future research on hands-free technology interaction is needed to develop intuitive interaction paradigms for smart glasses. Making interaction with smart glasses feel as natural as using a smartphone would open their use to a plethora of application fields.

One weakness of this research is that patients were not involved in the evaluation of the developed artifact. A promising avenue for future research is to evaluate how caregivers' use of smart glasses affects patient's trusting beliefs. Such insights could be valuable for designing new smart glasses and establishing usage guidelines.

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Digital Transformation in Health Care: Augmented Reality for Hands-Free Service Innovation

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Abstract

Health care professionals regularly require access to information systems throughout their daily work. However, existing smart devices like smartphones and tablets are difficult to use at the point of care, because health care professionals require both hands during their work. Following a design science research approach including ethnographic fieldwork and prototype tests with focus groups, we find that Augmented Reality smart glass applications offer potential for service innovation in the health care sector. Our smart glass prototype supports health care professionals during wound treatment by allowing them to document procedures hands-free while they perform them. Furthermore, we investigate the use of audio based and physical interaction with the smart glasses in a within-subjects design experiment.

Keywords Augmented reality · Health care · Digital transformation · Smart devices · Smart services

1 Introduction

As administrative burdens in health care have been increasing over the last years, caregivers have less and less time for direct patient care tasks (Seto et al. 2014; Vollmer et al. 2014). Employing smart devices to provide information access for caregivers at the point of care (POC) is thus a promising path to improve outcomes and reduce administrative burdens (van Rooij and Marsh 2016; Beverungen et al. 2017a). Smart devices allow health care service providers to retrieve and analyze aggregated field evidence and to dynamically adapt their service systems to the patients' needs (Beverungen et al. 2017c).

Rapid development and widespread deployment of smart devices are fundamental to many service innovations (Barrett et al. 2015). However, established smart devices like smartphones and tablets have not yet achieved large-scale adoption in health care. One of the main reasons for this is that health care workers often need both hands for their work, making it complicated to interact with the device during work (Czuszynski et al. 2015; Mitrasinovic et al. 2015).

Augmented Reality (AR) smart glasses, such as the Microsoft HoloLens, are a new generation of smart devices that have the potential to transform health care processes and health care management in general. These AR smart glasses augment their user's field of view with virtual information (Azuma 1997) and can complement or enhance service processes and workflows at the POC (Niemöller et al. 2017). They can be operated hands-free and do not encumber health care workers during their work while providing access to an information system.

Despite this potential, research on smart glasses in the service sector is still at a very early stage (Przybilla et al. 2018). In order to test potential use of smart glasses for smart services, we follow the design science research guidelines proposed by Sonnenberg et al. (Sonnenberg and vom Brocke 2012) to iteratively develop and evaluate artifacts that support health care workers. We thereby focus on wound management, as an exemplary service process within health care. Treatment of chronic wounds is a serious problem with high practical relevance in health care (Gillespie et al. 2014). In Germany, every year 2–3 million patients receive wound treatment. Among those, about 900,000 suffer from chronic wounds (Schubert and Köster 2015).

By testing smart glass and tablet applications with various design features in several focus group meetings with wound

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management experts, we find smart glasses to be promising for hands-free use. Yet, different options for technology interaction with smart glasses exist and it is unclear which method is most suited for daily use in health care facilities. Users can interact with the smart glasses using either audio based or physical interactions such as eye blinking. In order to determine technology acceptance and user satisfaction of these interaction techniques we conduct a repeated-measures experiment with 45 wound managers using a smart glass wound documentation prototype. Our experimental results confirm that wound managers are willing to adopt smart glasses for wound management and suggest that the preferred interaction method is subject to individual preferences.

2 Related Work

Literature reviews employed in Design Science Research should identify prior work that is relevant to the study, including theories, empirical research studies and findings/reports from practice (Gregor and Hevner 2013). In the following, we review prior research on smart service systems, theories of technology acceptance, empirical results of studies on AR smart glasses and reports from the practice of the wound management process in German health care facilities.

2.1 Smart Service Systems and Technology Acceptance

Organizations today desire strategies that place them on the frontiers of service innovation (Kim et al. 2015). Transformation of the existing service systems to a smart service system is thus a promising endeavor. Smart service systems are configurations of people, technologies, and other resources that interact with other service systems to create mutual value (Maglio et al. 2009). Smart service systems use smart devices, such as smart glasses, as boundary objects to network resources and routinize interactions between the actors involved in a service system (Becker et al. 2013). Smart devices can observe their environment through sensors or actuators while being able to communicate over a network and, thus, they can be active actors in a service system rather than just passive objects (Beverungen et al. 2017b). Collaborative systems will enable human individuals to realize their full creative potential in delivering services to consumers (Bednar and Welch 2019). Artifacts that are intended for smart service systems should be designed and built with an eye towards user satisfaction and technology acceptance (Jafari Navimipour and Soltani 2016). This is especially true in the health care context, where patient trust is essential (O'Connor and O'Reilly 2018).

Several models and theories of technology acceptance have been adopted from the fields of sociology and psychology and were tested in various information systems related contexts over the last decades (Venkatesh et al. 2003). The most-cited models are the Technology Acceptance Model (Davis et al. 1989), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003) and UTAUT2 (Venkatesh et al. 2012). Within our research, we decided to use UTAUT in order to evaluate our design artifact, because it was originally developed to explain employee technology acceptance and use (Venkatesh et al. 2012), whereas UTAUT2 focuses on consumer use (Venkatesh et al. 2012). UTAUT has previously been used in several instances to predict, define and enhance the use of information systems (Wills et al. 2008). The main factors in the UTAUT model are performance expectancy, effort expectancy and social influence that individuals experience when using an artifact. A vast body of research has shown that these constructs can predict an individual's intention to use the artifact, which in turn predicts actual use.

Additionally we investigated the satisfaction of caregivers after using our artifacts. Satisfaction refers to the perceived discrepancy between prior expectation and perceived performance after consumption. When performance differs from expectation, dissatisfaction occurs (Oliver 1980). Past studies suggest, that perceptions of service quality and value affect satisfaction, and satisfaction, in turn, affects loyalty and post-behavior (Chen and Chen 2010). The service profit chain directly links employee satisfaction and loyalty to customer satisfaction and loyalty (Loveman 1998). It posits, that internal service quality influences employee satisfaction, which in turn influences their loyalty which then influences service quality (Loveman 1998). Increasing internal service quality and employee satisfaction is thus likely to improve overall service quality. Moreover, health care workers' satisfaction with electronic patient records is considered to be a critical factor (Maillet et al. 2015). Finally, the adoption of new technology has been associated with increased job satisfaction (Bala and Venkatesh 2015).

2.2 Wound Management

Chronic wounds are a major problem in health care (Wüller et al. 2018). Every year 2–3 million German patients require wound treatment. Among those, approximately 900,000 patients suffer from chronic wounds. Chronic wounds are defined as wounds that require treatment for more than 8 weeks (Schubert and Köster 2015).

For the health care professionals in charge of treating the wounds, it is mandatory to provide an accurate documentation of the wound process (BVMed - Bundesverband Medizintechnologie e.V. 2015). This is not only required by German law but is also used as a basis for care quality assessment (BVMed - Bundesverband Medizintechnologie e.V.

2015). However, there is a lack of direction and there are no established standards on what tools to use for wound documentation (Ding et al. 2016). It has been noted that a more standardized approach to wound treatment documentation could help to shift from practice- to evidence-based wound treatment (Gillespie et al. 2015).

Wound documentation improves wound treatment outcomes, because relations between interventions and outcomes become evident (Ding et al. 2016). The wound documentation enables health care professionals to assess how the wound has changed over time. Thus, the wound documentation lays the foundation for professional therapy planning and ensures the best possible care for the patient.

The current practice of the wound documentation process is cumbersome to execute for the nursing staff and can lead to serious problems. These include the transmission of germs into open wounds. This may happen via the surfaces of digital cameras or similar devices, which are currently in use for image capture of wounds (Block et al. 2017). Nurses may touch such devices numerous times during the day without washing their hands, potentially spreading germs to others (Thomas et al. 2013).

Furthermore, the actual task of taking the photograph is challenging. Often, several nurses are required for such documentation. This makes it a time-consuming endeavor and adds to already high levels of workload. The documentation is typically written in the station room for hygienic reasons. The documentation is therefore written after the wound treatment is completed and is not done in a timely manner (Ding et al. 2016). Consequently, nurses have to remember specific details about the wound until they reach the station room. The resulting wound documentation is often described as inaccurate (Gillespie et al. 2015; Ding et al. 2016).

Several POC documentation systems, such as Physician-order entry systems or smartphone and tablet applications have been evaluated for use in the wound management context (Nuckols et al. 2014). However, POC systems whose functionality does not closely match the workflow are not valued by health care workers (Sockolow et al. 2014). A reoccurring problem with existing POC systems is that health care workers cannot use them when they do not have their hands free. This is especially problematic in health care where many procedures need to be performed aseptically (Hatscher et al. 2017). In this regard, smartphones, tablets and laptops are not well suited for documentation at the POC, because they should not be touched while the practitioner's hands are sterile or soiled.

In contrast to such hand-held devices, smart glass applications are much better fit for aseptic use in health care because they can be used hands-free. Virtual information is displayed in the user's field of view and technology interaction can be done through hands-free interaction modalities such as voice commands or eye blinking.

2.3 Augmented Reality Smart Glasses

The goal of AR is to bring additional information as seamlessly as possible into the view of a user (Schwald and de Laval 2003). This is done by adding real-time interactive virtual three-dimensional (3D) elements into the user's field of view (Azuma 1997). In previous research, usage of AR smart glasses has been evaluated in several service-related contexts (Klinker et al. 2018). In the field of Logistics, AR has been used to display assembly instructions and to support workers to pick the right parts from a shelf (Evans et al. 2017; Huck-Fries et al. 2017). Moreover, AR has been used for collaboration scenarios like minimal-invasive surgery (Chen et al. 2015).

Users of AR smart glasses need to be able to interact with the virtual objects surrounding them. As such devices are typically operated in mobile and 3D-environments, established interaction paradigms such as keyboard, mouse or the Windows Icons Menus Pointers (WIMP) are not a good fit for this technology (Jacob et al. 2008). Instead, physical 3D-interaction concepts like gestures, hand pointing, ray-casting with hand-held devices, eye blinking, gazing or audio-based interaction concepts like speech commands or natural language processing could be used (Bowman et al. 2008).

A selection technique for virtual objects has to provide means to indicate an object (object indication), a mechanism to confirm its selection (confirmation) and visual, haptic or audio feedback to guide the user during the selection task (feedback) (Sanz et al. 2013). Since selection consists of several subtasks, 3D user interfaces often leverage multimodal interaction techniques to achieve the synergizing effects of the division of labor. This can, for instance, be done by gazing at an object (indication) and speaking a voice command to select it (Klinker et al. 2017).

3 Research Approach

Research in IT that uses a design science paradigm is fundamentally proactive. Its goal is to create innovative artifacts that extend human and social capabilities and aim to achieve desired outcomes (Hevner and Chatterjee 2010). The objective of using design science research methods is to address a complex problem by developing and investigating the utility of the proposed solution artifacts (Gregor and Jones 2007). In our case, the aim of was to conduct research on service innovation using smart devices by focusing on one specific process in health care. Design Science research is typically initiated with an application context that not only provides the requirements for the research inputs but also defines acceptance criteria for the final evaluation of the research results (Hevner 2007). We selected the wound documentation process, because of its high practical relevance to health care workers, as described in section 2.2.

In order to design a wound management application to support health care workers during wound documentation, we followed the first three stages of the iterative build-evaluate design science approach proposed by Sonnenberg et al. (Sonnenberg and vom Brocke 2012). The incorporation of new information systems usually requires significant change to processes in an organization (Serrano et al. 2018). By following a very user-centered approach, we aim to increase acceptance of new solutions. Figure 1 shows a depiction of our research approach.

In our instantiation of Sonnenberg's framework, we first employed ethnographic research in order to gain an understanding of daily routines in the health care context and wound management. For this, we visited one hospital and two elderly care homes. Overall, we spent 60 hours each in the two elderly care homes and 40 hours in the hospital (Identify Problem). Throughout the ethnographic studies, we had the opportunity to watch 14 different health care workers throughout their daily work. Typical activities included washing patients, preparing and administering medicine as well as treating and documenting wounds.

After the ethnographies, we conducted a focus group meeting with nurses, care managers and care home managers in order to discuss problems with the wound documentation process and potentials for improvement (EVAL 1). There are four key reasons focus groups are an appropriate evaluation technique for design science research projects: Focus groups are a very flexible and open format that allow interaction with the respondents, yield large amounts of rich data and allow group participants to build on other respondent's comments (Tremblay et al. 2010). In total, 11 health care professionals with a nursing background as well as 2 leaders of health care facilities were present at the meeting. From the meeting, we derived a justified problem statement.

Design science is inherently iterative. The search for the best, or optimal, design is often intractable for realistic information systems problems (Hevner et al. 2004). In the second stage of our project (Design and EVAL2), we iteratively built low fidelity wound documentation artifacts (i.e. tablet and smart glass applications with various characteristics) and tested them with health care professionals individually and in three focus group meetings. The focus group meetings consisted of health care professionals with nursing backgrounds.

In the final phase of the project (Construct and EVAL3) we implemented a high fidelity smart glass wound management prototype on the Microsoft HoloLens and tested it in a repeated-measures experiment with 45 wound managers that is similar to the study design of Venkatesh et al. (Venkatesh et al. 2017). The goal of this phase was to validate the artifact design and to determine which 3D-interaction techniques are most suited for daily use in health care facilities.

3.1 Experimental Manipulations

We implemented two software versions of our wound documentation application. Each of them corresponds to a treatment within our experiment. The two applications were identical, the only difference being the interaction method. One used voice commands while the other used eye blinking. For the eye blinking treatment, we employed a Wizard of Oz approach (Maulsby et al. 1993). During the experiment, the trial manager would watch the participant's eyes and click on a Bluetooth device whenever the participant blinked twice with both eyes. We used the onboard voice command library of the HoloLens for the voice command version of the application. The available voice commands within an application screen were always displayed at the bottom of the participant's field of view. As the third treatment, we asked the participants to evaluate the wound documentation that is currently in use in their facility.

Overall, a total of two manipulated scenarios and one baseline scenario were presented to subjects: (1) the wound documentation process currently in use at the health care facility; (2) The HoloLens application using voice commands and (3) the HoloLens application using eye blinking. We did not combine the use of voice and physical interaction.

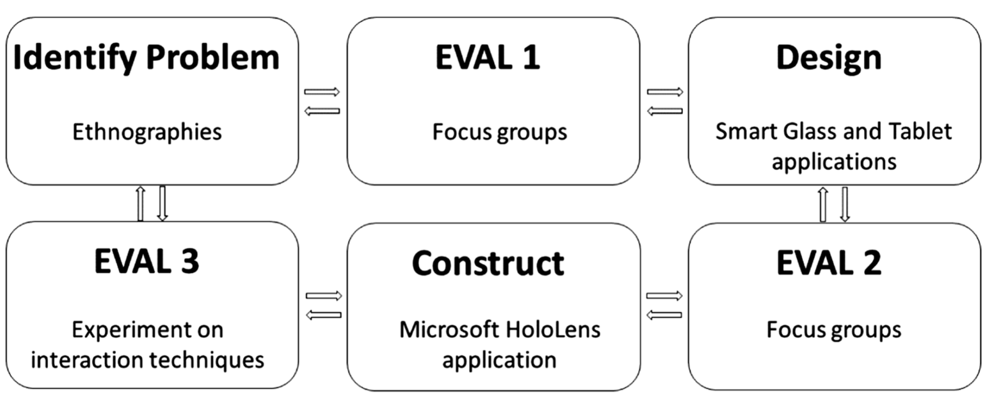

Fig. 1 Research approach

3.2 Data Collection

We conducted the experiment with the staff of health care facilities in quiet rooms within their own facilities. We used a table, two chairs, and a laptop with an online questionnaire. The online questionnaire consisted of several parts. In the first part, participants were asked for demographic data (i.e., gender, age, working experience and daily smartphone usage). The succeeding parts were identical and filled out after each treatment.

Data was collected using a closed online questionnaire. It contained questions on: Performance Expectancy (4 items), Effort Expectancy (4 items), Patient Influence (2 items), Behavioral Intention (3 items), nurses' satisfaction (4 items) and open comment sections after each treatment. Table 3 in the appendix lists all constructs and items as they were used in the study. Participants needed about 5 minutes on average to fill out one part of the questionnaire. Participants were asked to fill out one part of the questionnaire after each treatment.

The wording of the items used in prior studies was adapted to nursing practice. Since we were particularly interested in health care worker's perception of how patients would react to smart glasses in the wound documentation process, we changed the subject of the social influence construct to "patient" instead of "people who are important to me". Subsequently, one of the construct's questions became redundant and we dropped it. We decided to refer to this construct as "patient influence" instead of "social influence" throughout this research paper. Moreover, we changed the word "friends" in one of the questions for the satisfaction construct to "colleagues". Participants filled out a German version of the questionnaire. The question translations were derived from the appendices of published papers or upon request from German authors that used these constructs for evaluations (Nistor et al. 2014a, b; Rocznik et al. 2017).

3.3 Procedure

At the beginning of the experiment, we briefed the participants that they would be asked to document wounds as they would in their daily work. We simulated different wounds by providing printed pictures of different wounds for each treatment. For the treatments involving the HoloLens, we asked the users to test the application until they felt confident enough to use it on their own. We would then let participants do the experiment version of that treatment once. After each treatment, the participants were asked to fill out a questionnaire. In order to prevent learning and boredom effects from influencing our results, we randomized the order of the treatments.

3.4 Tasks

After having started one of the experimental treatments on the HoloLens, the user's first task was to measure the length of the wound. This is done by gazing at the far edge of the wound using the white cursor (indication) and then performing the confirmation command (using voice/blinking). A little blue dot then appears at the point the user is gazing at. Then the user needs to gaze at the near edge of the wound and repeat the selection command. A second blue dot and a line appear, connecting the two dots. Furthermore, the distance between the two dots is displayed above the line as a decimal number measured in meters. Figure 3 shows a picture of the result. By performing the next confirmation command a picture of the wound is taken. Using a red arrow, the user's attention is then guided to a virtual screen displaying the picture that was just taken. The user can either measure the wound again and take a new picture or proceed to the next steps.

The following screens are all checklists. On each screen, the user needs to check off all characteristics that the wound has. In total there are six checklist screens with four to six items each. Figure 4 shows a picture of one of the checklists. Once all checklists are filled in, the application returns to the main menu.

3.5 Participants

In total, we recruited 45 health care workers with wound management experience at four hospitals, three ambulant and two stationary health care providers. We approached senior level managers of the facilities and asked them for supporting our research by asking their staff to participate in an experiment about documenting wounds with a smart glass application. We then visited the facility and conducted the experiment with volunteers. The participants received no monetary compensation for their participation in the experiment.

The average age of the nurses was 40.48 years (standard deviation (SD) = 12.03) and they had 16.20 years of experience on average (SD = 11.63). The sample comprised 33 women (73.3%) and 12 men (26.6%). According to the German Federal Agency of Work, about 80% of nurses in the German health care sector are female (Bundesagentur für Arbeit 2018). Thus, we deem our experimental group to be a representative sample of nurses in the German health care sector.

Assuming a medium effect size ($f = 0.25$), with a power of 0.80 at alpha equals 0.05 significance level, the required sample size for each cell is 39 (Cohen 1992). Hence, 45 subjects for each experimental treatment is adequate for data analysis.

3.6 Factor Analysis

We used the standard procedure documented by Straub (Straub 1989) to validate the reflective constructs Performance Expectancy, Effort Expectancy, Patient Influence, Behavioral Intention, and Satisfaction. All factor loadings were significant, suggesting convergent validity. As suggested by Straub all constructs satisfy the threshold values for the average variance extracted ($AVE > 0.50$) and Cronbach's alpha ($\alpha > 0.70$) (Straub 1989). In order to evaluate construct reliability, we calculated composite reliability (CR) for all constructs. All constructs had a composite reliability significantly above the cut-off value of 0.70 and the constructs' quality is therefore satisfactory. Table 4 in the appendix shows AVE, CR and Cronbach's alpha for each construct used in this study.

4 Results

4.1 Ethnographic Results

During our ethnographic studies, wound experts mentioned several issues with the current wound documentation process that leave room for improvement. The most pressing issues stem from missing details in the documentation. For instance, wound details are often forgotten or wound measurements are often inaccurate. A second theme that emerged is related to the underlying process: In focus group meetings, wound managers described their present process to be inefficient and difficult to execute both time- and technology-wise. As an example, the issue of how to hold a ruler in place such that photos can be taken with a sense of scale has been raised. In addition, participants complained about the amount of material needed. Another major theme of issues relates to hygienic considerations: Wound managers expressed concerns about cameras not being disinfected, the need for frequent disinfection in the process, and the difficulty of adhering to hygienic standards. Taken together, while current processes seem to be based around a common core, they also seem to share deficiencies. The joint reports on unsatisfactory processes, e.g. regarding efficiency, and concerns regarding hygiene imply that health care practitioners find a lot to be desired in wound documentation.

To cope with deficiencies of current processes and to improve outcomes, health care workers employ various workarounds that may deviate from standard practices. Comments by participants have shown the following behavior: Some health care workers write down the wound size and other wound characteristics on paper or their hand directly after measuring in order to memorize them better (see Fig. 2). Others perform wound documentation with a second health care worker who writes down information on the paper ruler and takes the picture, while the other interacts with the patient and conducts the wound treatment. While such workarounds may increase outcome effectiveness, they also imply the risk of deviations in processes and thus consistency (Röder et al. 2014). Lack in consistency may be problematic since health care workers usually work in shifts and chances are, that future documentation will be carried out by different personnel, who then applies different standards. The resulting documentation may be hard to compare and thus contribute to the incomplete or unclear documentation.

Throughout the second phase of the project (Design and EVAL2), we identified several requirements and restrictions to the solution space. From the evaluations, it became apparent, that wound documentation systems need to be operated without having to touch them (e.g. by voice commands or body motions) and while the wound manager is at the patient's bedside. We came to this conclusion by testing a tablet application with wound managers. The idea for testing the tablet application was that it might be sufficient for wound managers to document the wound directly after wound treatment while they are still in the patient's room.

We evaluated the application in a focus group meeting. The wound managers in the focus group were not satisfied with the solution, because it did not improve the process sufficiently for them. Their concerns were, that they would not be able to look at the wound during documentation, because bandages would already be covering the wound. In this phase, we also tested a smart glass prototype on the Vuzix m100 that allowed for hands-free documentation using speech commands. We tested the prototype with wound managers in two focus group meetings and in six individual tests (EVAL 2). The findings of the focus group meetings are summarized in Table 1. The prototype was well received by the experts and viewed as a potential improvement to the wound documentation process. Wound mangers especially liked being able to document hands-free while performing the wound treatment. However, the experts wished for a feature that would help to measure the size of the wound. In the current process, paper rulers are being used for this. The experts stated that it is difficult to hold the paper rulers in place while taking a picture of the wound. Moreover, using a ruler holds the risk of transmitting germs into the wound and makes it difficult to stabilize patients.

Building on our design knowledge from the previous prototypes, we constructed our final prototype as a smart glass wound documentation application on the Microsoft HoloLens (see Fig. 3). We implemented a feature to measure the wound size using the Microsoft HoloLens's depth sensing capabilities and tested it with a focus group of wound management experts from a hospital. The experts liked the measuring feature and being able to document hands-free during wound treatment.

In contrast to the Vuzix m100, the Microsoft HoloLens uses Augmented Reality. While the Vuzix m100 only displays information on a small screen, the HoloLens embeds virtual objects into the real world. One of the main challenges that emerged during the construction of the final prototype was interaction with the virtual objects. Nurses needed to be able to select and deselect checkboxes about wound characteristics and measure wound sizes using a 3D User interface (see Fig. 4). In line with existing research, we employed a multimodal interaction approach in our application (Bowman et al. 2008).

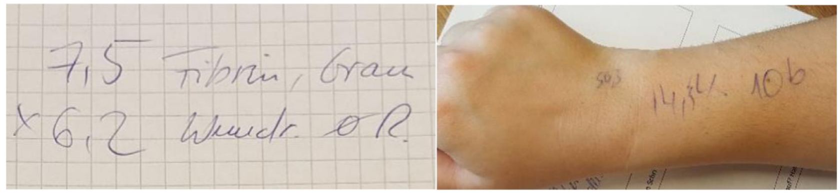

Fig. 2 Some health care professionals write down wound details during wound treatment in order to memorize wound details

We used gaze in order to indicate the object that should be selected and tested voice commands (audio based) and eye blinking (physical) for confirming the selection.

In the final project phase (EVAL3) we conducted an experimental evaluation of our artifact. The requirements throughout the project lead us to the conclusion, that a digital wound documentation system should be implemented on a mobile device that can be operated hands-free. This makes smart glasses a good fit for the task. From pre-tests of smart glass applications with health care professionals we deduced, that voice commands as well eye blinking (Aldaz et al. 2015) in combination with gaze were perceived as feasible technology interaction solutions. In order to assess what effect different technology interaction methods have on health care professionals, we conducted a repeated-measures experiment.

4.2 Experimental Evaluation of Hands-Free Interaction Techniques

The main goal of this experiment was to test user performance, satisfaction, and technology acceptance of health care professionals for different types of 3D interaction with smart glasses in the context of wound documentation.

Data associated with technology acceptance and satisfaction outcomes were analyzed with a repeated-measure ANOVA test with three within-subject factors as independent variables: The tool wound managers are using in their current process (1), voice commands (2) and eye blinking (3) using the wound management application on the HoloLens. To test differences between the treatments contrast tests, based on the Wilcoxon signed-rank test were used (Wilcoxon 1946). All significant results ($p < .05$) of the contrast tests are reported in the "Comparison"-column of Table 1. In addition, Table 1 also reports means, variances and completion times. Due to problems with the logging system on the HoloLens only $n =$ 33 datasets could be used for the evaluation of the completion times. In addition, the completion times of the current process were not measured during the experiment. The results of the experiment are reported in Table 2.

5 Discussion

The experiment results show that smart glass-based documentation systems are viewed significantly more favorable in terms of Performance Expectancy, Behavioral Intention and Satisfaction compared to existing documentation processes.

From comments in the questionnaire, we deduce that some wound managers did not like eye blinking because repeated blinking is uncomfortable with contact lenses. However, generally speaking, health care professionals seem to prefer eye blinking over voice commands. On average, health care workers needed significantly less time (31.06%, 38.72 s) to complete documentation using eye blinking. They also reported significantly higher levels of satisfaction for eye blinking as compared to voice commands.

We can only speculate why participants were faster using eye blinking. One factor might be that participants needed to

Table 1 Findings of the focus group meetings

Shortcomings, workarounds and potential improvements of the existing wound management process	
Current shortcomings	Wound documentation is not done at the patient's bedside
	Documentation is often inaccurate or incomplete
	Wound documentation is difficult to perform both time- and technology-wise
	Objects like rulers and cameras need to be touched during the procedure, which raises hygienic concerns
Existing workarounds	Wound information is first written down on paper and transcribed to the information system later
	Colleagues are often asked to assist during the procedure
Potential improvements	Wound management should be performed hands-free
	Wound documentation should occur at the patient's bedside
	Wound managers need a tool that helps them measure wound sizes hands-free

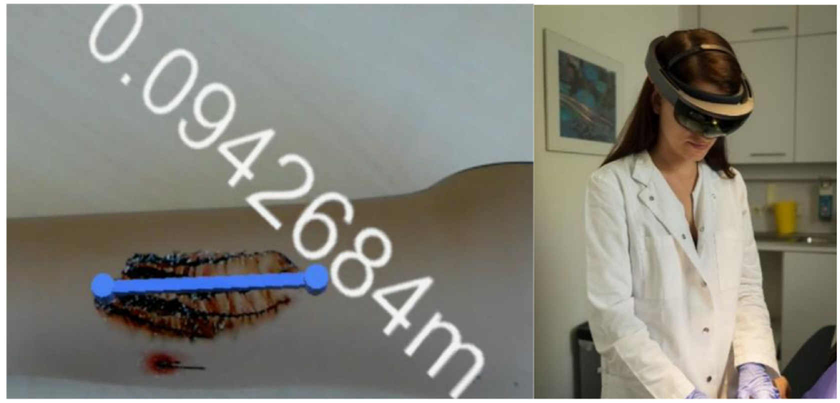

Fig. 3 Measuring the wound size with the Microsoft HoloLens

use different voice commands. Available voice commands were always displayed in the participant's field of view (e.g. see Fig. 4). Having to look up individual commands might have slowed participants down. Another explanation could be that we employed a Wizard of Oz approach to simulate the eye blinking treatment, whereas we used the onboard voice command library of the Microsoft HoloLens for the other treatment. While we are quite certain that participants did not notice the Wizard of Oz approach, it is possible that it could have reduced the completion times.

Interestingly, despite the current documentation process receiving unfavorable outcomes for every other construct, we found no significant effects could be reported for patient influence. An explanation for this might be that experiment participants found it difficult to assess how patients would react to them wearing smart glasses while treating their wounds. This should be investigated further in future research.

5.1 Theoretical Implications

Gregor et al. specify a 2 × 2 framework of design science research contexts that can help to classify research endeavors into the quadrants of invention, improvement, exemption and routine design (Gregor and Hevner 2013). The axes of this framework are application domain maturity and solution maturity. The health care sector and specifically the process of wound management are a well-established problem context. Yet, AR smart glasses are an emerging technology that currently still inhibit at a low solution maturity. Thus, our research effort falls into the improvement quadrant. The goal of Design Science research in the improvement quadrant is to create better solutions in the form of more efficient and effective products, processes, services, technologies, or ideas (Gregor and Hevner 2013).

Health care providers all over the world are faced with the challenge to improve patient outcomes while containing costs. The digital transformation is recognized as a key component to tackle this challenge (Gopal et al. 2019). Due to hygienic requirements hands-free technology interaction is often required in the health care sector (Hatscher et al. 2017). Established smart devices like smartphones and tablets are not an optimal fit. Since it is possible to use AR smart glasses hands-free, we deem evaluation of AR smart glasses for process improvements in the health care sector to be a worthy research endeavor.

A necessary precondition for usage of AR smart glasses in the health care sector is technology acceptance of such devices by the health care workers. We used a

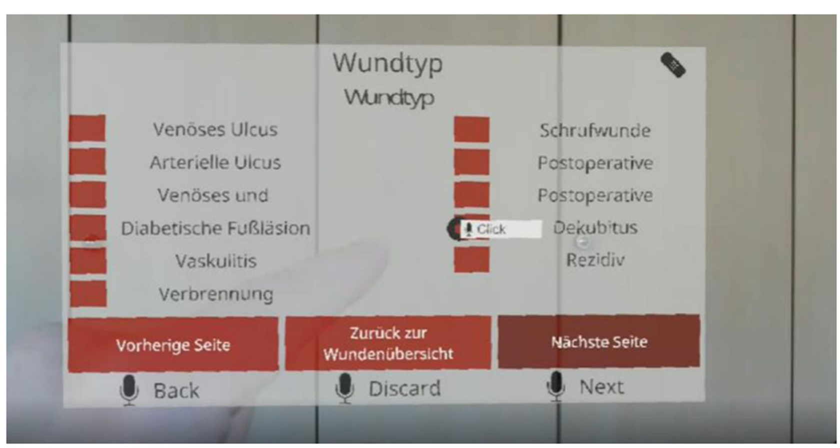

Fig. 4 Picture of one of the checklists. The black circle indicates what the user is gazing at. The option can be confirmed by saying the voice command "Click"

Table 2 Experiment results (p value significance level: *.05, **.01, ***.001). Completion times are reported in seconds, while all other variables are 7-point Likert scales

Outcomes	(1) Current process		(2) Voice commands		(3) Eye blinking		Comparison
	M	SD	M	SD	M	SD	
Performance Expectancy	4.33	1.33	4.94	1.55	5.47	1.42	3 > 1***, 2 > 1*,
Effort Expectancy	5.08	1.15	5.34	1.42	5.74	1.24	3 > 1**
Patient Influence	4.76	1.34	4.52	1.65	5.08	1.41	No significant effects
Behavioral Intention	4.15	1.59	4.87	1.50	5.19	1.44	3 > 1**, 2 > 1*
Satisfaction	3.89	1.58	5.09	1.42	5.63	1.27	3 > 1***, 2 > 1***, 3 > 2*
Completion times	NA	NA	124.66	90.02	85.94	32.59	3 > 2***

design science approach to investigate design principles for AR smart glasses for usage in health care. Design Science research can make contributions on three Levels. These Levels range from specific instantiations in the form of products and processes at Level 1 to more abstract contributions at Level 2 in the form of nascent design theory (e.g., constructs, design principles, models, methods, technological rules), to well-developed design theories about the phenomena under study at Level 3 (Gregor and Hevner 2013). This research makes contributions on Levels 1 and 2. We have built several instantiations of wound management artifacts. From evaluations with these artifacts, we have derived knowledge that we consider to be contributions that specifically apply to the wound management process:

First of all, through an evaluation of a tablet application, we were able to confirm that hand-held devices are not viewed favorably by health care workers for the process of wound management. Secondly, it became apparent that health care workers prefer to fill in the wound documentation in the patient's room while being able to look at the wound. Third, the evaluation of our two smart glass prototypes showed that health care workers require a measurement feature that allows them to measure wounds hands-free. Finally, our evaluation results suggest that health care workers would accept and be satisfied with using smart glasses for wound documentation.

Our study also allows us to put forward design principles that are not limited to the wound management context but pertain to the broader context of hands-free technology interaction. Previous studies in the fields of 3D-User Interfaces and AR have pointed out that real-world evaluations on usability and effectiveness of different technology interaction methods is necessary (Billinghurst et al. 2015; Datcu et al. 2015). We show that eye blinking in combination with gaze is a viable solution for hands-free technology interaction in the health care context. However, our study also shows that the preferred technology interaction methods are subject to individual preference. A possible solution to address this would be to offer alternative technology interaction modalities.

5.2 Practical Implications

Practitioners will also profit from this research. Our research shows that AR smart glasses are a promising technology for supporting the wound management process. The description of our research and the proposed design principles can help smart glass manufacturers and software developers to design solutions tailored to the needs of health care workers. Since about 900.000 people in Germany require wound treatment on a regular basis this could be a promising business opportunity (Schubert and Köster 2015).

Moreover, the demographic change and increased life expectancy in our society will likely increase the demand for wound treatment and other health care services in the future. Therefore, more jobs are likely to be created in the health care sector. Patient care is an integral part of health care systems (Chandwani 2017). Yet, many health care facilities are already lacking personnel. One way of making job profiles in health care more attractive could be the transformation of existing service systems to smart services systems. Finally, positive innovation cases could incentivize health care providers to invest further into new innovative approaches in order to catch up to digitization levels of other service domains.

6 Limitations and Future Research

Our study has several limitations. Firstly, we focused on the health care workers' perceptions of our artifact, leaving out the patient's perspective. Health care workers have told us that they cannot predict how patients would react to it in a real-world setting. Wound documentation involves taking pictures of patients in an intimate setting and is therefore related to trust and privacy. Privacy concerns can significantly diminish employee's willingness to adopt new technologies (Yassaee and Mettler 2017). Future research involving patients could yield interesting insights into patient influence, privacy concerns and trust related factors.

Our experimental evaluation has some weaknesses: Since wound documentation processes are not standardized and differ amongst health care providers, we were not able to align our artifact with the participants' documentation habits. Furthermore, we concentrated our research efforts on German health care providers. The legal situation pertaining to wound management documentation is likely to differ among countries. The generalizability of our results is therefore limited to Germany. Moreover, our evaluation of the interaction methods is subject to the usability and quality of implementation. Future research should implement and evaluate further artifacts for mobile and hands-free technology interaction in order to validate our findings.

Within our research, we focused on one specific use case within the health care sector. In order to digitally transform the health care sector identification of further use cases and design science research to meet these use cases is required. Furthermore, use cases similar to wound management exist in other service domains. For instance, maintenance technicians need to regularly document maintenance activities they perform on machines, where mobile and hands-free information access is helpful. Future research could build upon our technology interaction recommendations to build helpful artifacts in these domains.

Lastly, usage of smart glasses in smart service systems implies interesting options for artificial intelligence. Artificial intelligence could detect and automate process steps. For instance, the smart glass cameras could be used to recognize a patient's wound, automatically measure its size and save it to the patient's health record. Building upon such capabilities it might be possible to monitor, prioritize and distribute tasks within a smart service system of health care workers wearing smart glasses.

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Appendix

Scales used

Table 3 Scales used in the study

Constructs (citation)	Items
Performance Expectancy (Venkatesh et al. 2003)	PE1: I would find the documentation system useful in my job.
	PE2: Using the documentation system enables me to accomplish tasks more quickly.
	PE3: Using the documentation system increases my productivity.
Effort Expectancy (Venkatesh et al. 2003)	EE1: My interaction with the documentation system would be clear and understandable.
	EE2: It would be easy for me to become skillful at using the documentation system.
	EE3: I would find the documentation system easy to use.
	EE4: Learning to operate the documentation system is easy for me.
Patient Influence (Nistor et al. 2014a)	PI1: Patients would think that I should use the documentation system.
	PI2: Patients would prefer that I use the documentation system.
Behavioral Intention (Venkatesh et al. 2003)	BI1: I intend to use the documentation system in the future.
	BI2: I predict I would use the documentation system in the future.
	BI3: I plan to use the system in the future.
Satisfaction (SF) (Ding et al. 2011)	SF1: It was the right thing to use the documentation system
	SF2: I have truly enjoyed using the documentation system.
	SF3: My choice to use the documentation system was a wise one
	SF4: I am satisfied with the documentation system

Scales used in the study were in German. The German scales are available upon request from the authors.

Composite Reliability, Average Variance Extracted and Cronbach's Alpha

Table 4 Composite Reliability, Average Variance Extracted and Conbach's Alpha of the final experiment

Construct	Composite Reliability	Average Variance Extracted	Cronbach's Alpha
Performance Expectancy	0.92	0.81	0.91
Effort Expectancy	0.89	0.73	0.89
Patient Influence	0.93	0.87	0.93
Behavioral Intention	0.95	0.86	0.95
Satisfaction	0.93	0.79	0.93

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CONCEPTUALISING PASSIVE TRUST: THE CASE OF SMART GLASSES IN HEALTHCARE

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Abstract

In recent years the digitisation of healthcare has been moving forward. Emerging technologies, such as smart glasses, are being tested for allowing healthcare workers information access at the point of care, while being able to work hands-free. Yet it remains unclear how the use of smart glasses will affect the trust relationship between patients and caregivers. The patient is not an active user of the smart glasses but is nevertheless dependent on outcomes influenced by the smart glasses. The patient, therefore, becomes a passive trustor of this technology. Building upon existing trust research literature, we present a research model and extend it by interviewing 20 patients about their experiences with caregivers and their perceptions regarding the use of smart glasses in healthcare. We find that communication with patients is a key driver of passive trust in technology and trust in caregivers. This research contributes to a better understanding of the trust relationship between patients and caregivers and provides insights into the construct of passive trust in technology. In order to extend the qualitative data analysis, future research should investigate the extent of the acceptance of smart glasses by patients within healthcare facilities.

Keywords: Smart Glasses, Passive Trust, Healthcare.

1 Introduction

As more and more time in healthcare is being spent on administrative tasks, there is less time for direct patient care tasks (Seto, Inoue and Tsumura, 2014; Vollmer, Prokosch and Bürkle, 2014). The spread and use of technology is rapidly increasing in the healthcare sector. From documentation, through operations support, to patient monitoring, the reach and support of information technology is growing (Brickel, Montague and Winchester, 2012). IT systems to support information logistics and communication are already in use in many hospitals (Ammenwerth et al., 2011). The implementation of hospital information systems (IS) promises benefits for hospitals, doctors and patients (Venkatesh, Zhang and Sykes, 2011; Wüller et al., 2018). Yet providing information access for service processes at the point of care (POC) remains a promising endeavour to improve outcomes and reduce administrative burdens (van Rooij and Marsh, 2016).

In recent decades, various portable devices have been developed for a variety of purposes and applications (Sultan, 2015). Wearable hands-free systems like Augmented Reality (AR) smart glasses, the Microsoft HoloLens for example, are a promising new development that may have the potential to transform healthcare processes and health management in general (Klinker et al., 2018). These AR smart glasses augment reality with virtual information (Azuma, 1997) and have the potential to complement or enhance service processes and workflows at the POC, while working hands-free (Huck-Fries et al., 2017; Klinker, Fries, Wiesche and Krcmar, 2017; Klinker, Wiesche and Krcmar, 2019).

On the other hand, smart glasses might also have negative side effects in terms of patient trust. Patient-doctor communication is the backbone of the primary care visit, since it influences patient trust (Asan, Tyszka and Fletcher, 2015). Patient trust can, in turn, influence patient satisfaction (Chang, Chen and Lan, 2013), opt-in intentions (Angst and Agarwal, 2009), adherence to treatment and clinical outcomes for patients. Smart glasses may disturb, disrupt, alter (Due, 2015), or impair social interaction (Jacquemard et al., 2014) and thus, may call for a new social etiquette (Due, 2014).

Existing trust research has dealt with trust in humans and trust in technology as separate topics. Moreover, IS research on trust in technology has always assumed a perspective where the trustor is an active user of a technology. However, in this case the patient becomes a passive trustor of the technology, while the healthcare worker is the active user of the technology. The experience for the patient who faces technology used in their treatment is called passive trust in the present work. So far, this type of trust has not been much studied in the literature. Xu et al. differentiate between active and passive users in socio-technical systems (Xu, Le, Deitermann and Montague, 2014; Lee, Montague and Xu, 2015). Montague, Kleiner, and Winchester deal with patients' trust in medical technologies (Montague, Kleiner and Winchester, 2009). In research about medical technologies, researchers have pointed out that trust in technology in the medical field differs from trust in technology in other areas (Montague et al., 2009).

This leads us to our research question: *How do technological enhancements of humans affect trusting beliefs within their social environment*?

While this research question is rather broad and probably exceeds the scope of one study, we intend to tackle it by conducting exploratory work in the healthcare sector. So far, we have already conducted several interviews with individuals about their experiences in healthcare facilities using the critical incident technique (CIT). Building upon insights from these interviews, we propose a research agenda for future work on this topic. In the following section we provide a brief overview of existing trust research and how it relates to our topic.

2 Background

There are many relationships of trust. Trust research can be split into trust (1) between people or between groups, (2) between people and organisations, (3) between organisations, and (4) between people and technology (Söllner, Benbasat, et al., 2016). In general, trust is defined as a latent variable made up of different dimensions (Bühner, 2011). Confidence plays an important role in decision-making (Gefen, 2000), including, for example, consumer buying intentions (Oliveira, Alhinho, Rita and Dhillon, 2017) or the decision to use a technology (Lee and See, 2004) and is a key factor in social behaviour (Gefen, 2000). In this work we define trust according to Mayer, Davis, and Schoorman (Mayer, Davis and Schoorman, 1995) as follows:

'Trust is the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party' (Mayer et al., 1995).

2.1 Active Trust in Technology

Similar to trust in people, trustors value the ability of a technology to perform defined tasks (McKnight, Carter, Thatcher and Clay, 2011). The decision to use a technology is therefore influenced by the perceived properties of the technology (Moore and Benbasat, 1991). The dimension's ability, integrity and benevolence have been translated from the human domain into the technological context. While ability in interpersonal confidence describes the competences and attributes of a person to fulfil a promise in a particular context, in the technological context the functionality of a technology is evaluated. Users estimate the extent to which a technology has certain functions available to perform a particular task. Integrity reflects the extent to which the technology acts consistently, reliably and according to accepted principles. In the technological context, integrity is replaced by reliability. It evaluates the consistency of all functions. Despite the lack of free will of a technology, this can be faulty (McKnight et al., 2011). Technology follows pre-engineered algorithms or logic. The transfer of benevolence into the technological context is, thus, not permissible, since no adequate comparison can be made with human decision-making (Söllner, Hoffmann, Hoffmann and Leimeister, 2011). Despite the lack of a mortal body, users assess how appropriate, effective and fast the built-in help function of a technology works in providing useful advice. Helpfulness is the third dimension of trust in technology (McKnight et al., 2011).

2.2 Passive Trust in Technology

According to Montague and Xu, a passive user is defined as an individual with limited control over the technologies and IT artefacts used in a system (Xu and Montague, 2012). Nevertheless, passive users are directly affected by the results and the outcome of technology use. A passive user can observe the actions and interactions of the active user with the technology and use these perceptions to assess the functionality and reliability of a technology. Inbar and Tractinsky refer to passive users as random or casual users of a system (Inbar and Tractinsky, 2009). They define the passive user as the co-user of a system that has interests in the data that comes from interactions. In addition, the passive user is influenced by the technology and the active user. A communication of the passive user with the system is only conditionally possible, or is moderated by the active user (Inbar and Tractinsky, 2009). The limited influence of the passive user inherent in an inability to control the system, can lead to insecurity and anxiety in the interaction (Inbar and Tractinsky, 2009). Although passive trust has been mentioned in various contexts, little empirical research on this topic can be found. Moreover, passive trust has not been integrated with and delimited by existing trust research.

Very little IS research has focused on the passive user perspective. This finding is supported by Söllner et al., who find that IS research on trust has mainly focused on the trust relationship between the user and the information system itself, largely neglecting that other targets of trust might also drive IS use from a user's point of view (Söllner, Hoffmann and Leimeister, 2016). For instance, in their research they found trust in the provider to be as important as trust in the IS itself. Furthermore, McKnight et al. found that users' institution-based trust in the Internet and their trust in a specific web vendor need to be in place before they are willing to conduct business with a specific vendor via the Internet (McKnight, Choudhury and Kacmar, 2002). Angst and Agarwal assessed whether patients could be persuaded to change their attitudes and opt-in behavioural intentions towards electronic health records (EHR) (Angst and Agarwal, 2009). They found that an individual's concerns for information privacy (CFIP) interacts with argument framing and both affect attitudes towards the use of

EHRs. Furthermore, their results suggest that attitudes towards EHR use and CFIP directly influence opt-in behavioural intentions

Transferred to the medical context, patients are passive users of medical technologies, while physicians and nurses are active users. Passive trust in technology is introduced as a new construct for measuring the trust in technology of a passive user. Trust in the caregiver or physician is a prerequisite for positive patient outcomes and a key factor in determining patient satisfaction and safety (Mosad, 2015). Chang, Chen, and Lan (Chang et al., 2013) highlight the influence of trust in interpersonal interactions in the service sector. Likewise, quality care can only be achieved through a good caregiver-patient relationship (Strandås and Bondas, 2018). The conceptualisation of trust in the relationship is characterised mainly by the power imbalance between the patient and the caregiver, which increases the vulnerability and dependence of the trustor, i.e. the patient (Dinç and Gastmans, 2013). Previous studies usually dealt with only one perspective, and seldom considered the patient's side and the caregiver's side alike (Strandås and Bondas, 2018). Pearson and Raeke (Pearson and Raeke, 2000) examine patient confidence in physicians, citing ability, compassion, confidentiality, reliability and communication as the key drivers. Communication (Asan, Tyszka and Fletcher, 2016) and getting to know the patient (Strandås and Bondas, 2018) are often considered the key factors for trust relationships in the medical context.

Trust also plays a critical role in determining which technologies and applications are implemented and used in patient-centred care (Ezezika, 2015). On the other hand, the use of technology can limit or alter the communication between medical staff and patients, which in turn affects the relationship of trust. The sometimes negative effects of using electronic medical records in communication have already been investigated (Street et al., 2014).

3 Initial Exploration

Data was collected in 20 semi-structured interviews with former patients of the German healthcare system between June and August 2018. Twenty people were selected for interview who had personal experience as a patient in a hospital or doctor's office. Of the participants (N = 11) 55% were female. The average age was 42.5 years (SD = 19.86). All respondents were asked to rate their computer skills at the beginning of the interview, and to assess their experience with AR and smart glasses. A scale from 0 (no experience/knowledge) to 4 (comprehensive experience/knowledge) was used. On average, participants have computer experience of 19 years (SD = 5.68) and rate their computer literacy at 2.45 (SD = 1.05). Experience with AR averaged 0.3 across all participants (SD = 0.57), while smart glasses experience averaged 0.64 (SD = 0.73). The participants had the following academic degrees: intermediate (N = 2), high school (N = 3), bachelor (N = 3), master or equivalent (N = 11), doctorate (N = 1). The technique affinity rating on the above-mentioned scale averaged 2.45 (SD = 0.76) across the sample.

All interviews were logically divided into two sections. The focus of the first part of the interviews was to explore the construct of passive trust and to build up knowledge about possible factors and dimensions of the construct in order to refine the research model.

In order to assess the first part of the interview from which we wanted to gain insights into the patient-caregiver relationship, we used the Critical Incident Technique (CIT). CIT has been increasingly used in recent years for research in healthcare (Bradbury-Jones and Tranter, 2008). The role of the caregiver, as well as the perspective of patients and interactions between caregivers, doctors and patients can be successfully understood and described by the CIT (Schluter, Seaton and Chaboyer, 2007). The method is particularly suitable for researching little-known constructs and gives first indications of influencing factors and possible dimensions (Butterfield, Borgen, Amundson and Maglio, 2005). For our study, we adapted the semi-structured interview guides proposed by Norman et al. and Rous and McCormick to our context (Norman, Redfern, Tomalin and Oliver, 1992; Rous and McCormick, 2006).

The aim of the second part of the interview was to gain insights into the patient perspective regarding caregivers using smart glasses. Interviewees were presented with four pictures of caregivers wearing smart glasses. They were given the following hypothetical scenario:

Imagine that you had a serious operation on your hand and you now have a wound that needs to heal. You are lying in hospital for a few weeks. A nurse comes into your room every day with a pair of smart glasses. With the help of the glasses, the nurse measures the size of the wound and takes photos from different angles to document the wound.

4 Preliminary Results

All interviews were subjected to a qualitative analysis according to a grounded theory approach (Corbin and Strauss, 1990). A hierarchical code schema was developed. During coding, newly introduced codes were iteratively compared to existing codes, to identify similarities or differences and to ensure consistency in coding. Similar codes were grouped into subcategories. In the following we will report our main results. The number of times a topic was mentioned is indicated by the variable k.

4.1 Interviews with Critical Incident Technique

All positive technology perceptions experienced by patients mentioned during their visits to healthcare facilities can be assigned to the categories ‘interest’ (k = 3), ‘reliability’ (k = 5) and ‘functionality’ (k = 7). The subcategory ‘interest’ suggests that personal involvement and curiosity regarding the functions and characteristics of a technology positively influences passive trust in technology. This indicates that the constructs of reliability and functionality that we have transferred from the active trust context also apply in the passive trust context.

The negative technology perceptions can be divided into the subcategories of ‘technology properties’ (k = 10) and ‘functionality’ (k = 1). Among technology properties, statements about the size, volume and age of a technology and other confounding factors are summarised. Patients rated technologies as negative in part because of their underlying mechanisms. For example, x-rays are considered a negative medical technology because many consider the technology dangerous and unhealthy. Due to the frequency of the statements, it can be assumed that not only the functionality of a technology, but also its external characteristics affect patients in their perception and thus impact their trust. When designing and introducing such technologies, care should be taken to explain unpleasant characteristics in order to avoid patient insecurity.

In addition to technology perceptions, the interviews were examined for positive and negative personal influences. Positive influences of persons were subdivided into the categories ‘caring’ (k = 8), ‘information and communication’ (k = 18) and ‘professionalism’ (k = 9). The negative influences were divided in the categories ‘missing control’ (k = 12), ‘information and communication’ (k = 16) and ‘motivation and motives’ (k = 6).

Benevolence, as a positive influence, encompasses all the situations described, in which caregivers showed compassion and patience for the well-being of a patient. The results confirm that benevolence, as an important dimension of personal trust, also plays an important role in the trust relationship between patients and caregivers. The relationship with the medical staff is especially important for the patients. Illness and pain induce feelings of insecurity and anxiety in the patient, so, especially in these moments, the care of another person is of particular importance.

Information and communication are perceived to be both positive and negative. Positive statements imply that malaise and anxiety can be reduced through explanations and education. Communication with the medical staff have positively influenced a situation in many cases. Explanations that positively influence a patient-caregiver relationship are often described by their level of detail. The temporal component also plays a role here. Patients want to be informed as soon as possible about treatments, diagnoses and their state of health. Negative statements in this category almost exclusively refer to the lack of information and education. Patients describe uncertainty and anger about being poorly informed or uninformed about treatments and diagnoses. In addition, respondents attach great importance to receive the reasoning for medical advice. Patients have very little influence on their own destiny. They rely completely on doctors and nurses and their ability to heal them. Knowing what is being done, for what purpose it is done and how it is done, at least gives the patient some degree of control over the situation. From the interviews, it is clear that communication and information are the basis of a good patient-nurse relationship.

Among the positive influences is the subcategory of professionalism. The statements show that patients consider a competent caregiver 'professional'. A clean and quick execution of activities is perceived positively by patients and increases their confidence in the caregiver. When mistakes happen or important checks are forgotten, trust in medical personnel decreases. When patients question the motivation and motives of medical staff, it negatively affects their trust in that person. A person who puts personal profit before the well-being of the patient is perceived as incompetent and the trust decreases.

4.2 Patient Feedback on the Hypothetical Smart Glass Scenario

Patients offered many positive views on the use of smart glasses in healthcare. For the positive assessments the categories were 'cooperation' (k = 1), 'avoidance of mistakes' (k = 8), 'general improvements' (k = 22), 'suitability for the use case' (k = 11), 'innovation and progress' (k = 10), 'Efficiency and time savings' (k = 11) and 'work relief' (k = 6) were formed.

Without much knowledge of smart glasses or the specific application, patients mentioned many advantages of integrating smart glasses into patient-related care. The interviewed patients rated the application as very innovative and progressive, and suitable for the application of medical documentation. The subjects were mostly interested and amazed by the technical possibilities. Patients thought that the application has the potential for improving the process. One person noted the possibility of improved collaboration and communication among medical staff. Many respondents see the use of smart glasses as having the advantage of avoiding errors through a regulated documentation process. Many interviewees were generally very positive about technical progress in the medical field.

In addition to the various positive reviews, some negative aspects also came up. The negative ratings can be summarised as 'scepticism, alienation and anxiety' (k = 23), 'data security and transparency' (k = 4), 'shame' (k = 5) and 'eye contact and personal attention' (k = 10).

None of the interviewees mentioned only positive or negative points. Most of the negative comments can be grouped into the category 'scepticism, alienation and anxiety'. Some of the interviewees said that they felt uncertainty or fear at the sight of a caregiver with smart glasses. Others were sceptical about smart glasses improving the quality of care, but instead leading to caregivers being put out of their jobs. A lot of comments were linked to missing eye contact. Many of the interviewed patients stated that lack of eye contact with the caregiver was the reason for their scepticism and insecurity. Two interviewees said they were worried about data storage in the new system and that they value transparency in data handling.

All patients were asked if the location of the wound would be important to them if the documentation was done with smart glasses. 25% (N = 5) of all respondents answered this question with a yes. However, three of these individuals stated that their answer had nothing to do with the documentation system. In general, the location of the wound affects feelings of shame or uncertainties.

5 Research Model

In the following we present our research model and explain all relevant constructs that are used in it. Figure 1 shows a depiction of our research model. In the following we will explain the constructs that are used in the model.

The opt-in intention for a new technology is defined as the general willingness of a patient to consent to the use of this technology in their treatment and care (Angst and Agarwal, 2009). This intention may indicate a patient's later acceptance or rejection of the technology (Montague, Winchester and

Kleiner, 2010). The satisfaction of a patient with the medical services received is an important indicator for hospitals and medical staff, as it is possible to draw conclusions about the quality of services. The relationship between medical staff and the patient, as well as the patient's trust in medical staff, can positively influence patient satisfaction (Chang et al., 2013). We use the constructs of satisfaction and opt-in intention as outcome variables in our research model.

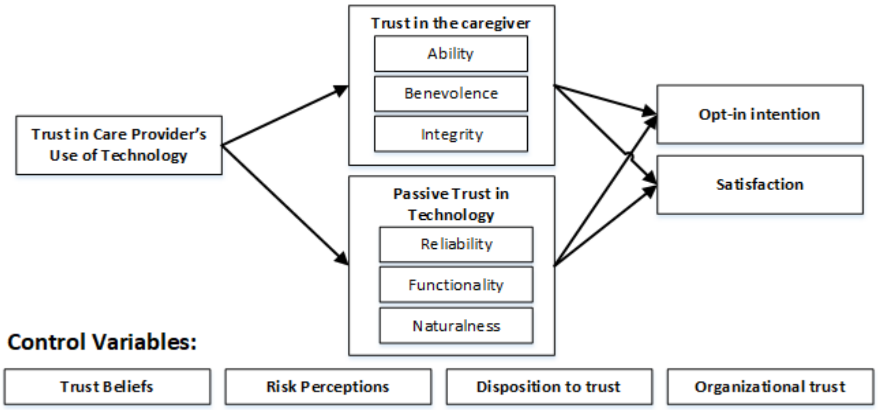

Figure 1. Research Model

Mayer et al. (Mayer et al., 1995) describe interpersonal trust as an assessment of the ability and attributes of another person to act as expected in a risky situation. Interpersonal trust encompasses the construct's ability, benevolence and integrity (Mayer et al., 1995). The construct ability refers to all abilities, competencies, and properties that enable an individual to exert influence in a particular domain (Mayer et al., 1995). McKnight, Choudhury, and Kacmar define the construct as the ability to do for the other person what needs to be done for them (Harrison McKnight et al., 2002). Benevolence is the evaluation of the extent to which another party, apart from one with an egocentric profit motive, acts in the interest of another (Mayer et al., 1995). Integrity refers to values and principles of another party (Mayer et al., 1995). Of particular interest here is the impact of the use of smart glasses on assessing the ability and benevolence of a caregiver by the patient. Within our research model we refer to interpersonal trust and its constructs ability, benevolence and competence as 'trust in the caregiver'.

Trust in a specific technology reflects confidence in a specific technology, beliefs and impressions about the beneficial features and characteristics of the technology (McKnight et al., 2011). The authors assume that users know the technology so well that they can predict how they will react under different conditions (McKnight et al., 2011). Since this research model describes the trust of patients and patients are passive users who neither control nor see the technology itself, not all of the dimensions of trust of McKnight et al. (McKnight et al., 2011) are applicable in this context. Only reliability and functionality can be assessed by patients through an observation of the active user.

The trust of patients in medical technologies is gaining importance as digitalisation in healthcare continues. Technology can change the context of human relationships and interactions and thus influence trust in the caregiver (Jarvenpaa, Shaw and Staples, 2004). Patients' impressions of how the caregiver handles the technology are thus likely to impact their trust in the caregiver and the technology (Montague et al., 2010).

Moreover, we have added several control variables to our model that are known to have an influence on trust and might have an influence in the healthcare context. These constructs are: trust beliefs (Lang, Wiesche and Krcmar, 2017), risk perceptions (Fox and Connolly, 2018), disposition to trust (McKnight, Choudhury and Kacmar, 2002) and organisational trust (Lang, Wiesche and Krcmar, 2018).

6 Conclusion and Future Research Agenda

The evaluation of the interviews showed that patients have mixed feelings about the use of smart glasses in delivering their care. The interviewees commented that initial eye contact is essential for them to build trust in the caregiver. This supports results of Riedl et al. who argue that human faces help to build trust (Riedl et al., 2014). The results also show that patients want to retain as much control as possible during treatment. Extensive patient education and information on measures, diagnoses and applied technologies give the patient the feeling of being able to control the situation.

The results support the assumption that reliability and functionality are dimensions of passive trust in technology similar to research findings in the active trust literature (McKnight et al., 2011). Technology characteristics such as shape, appearance and size have also been identified as a potential dimension of passive trust in technology. It is also possible that further constructs, which are relevant to the context of passive trust, have been not been uncovered in this initial phase of our research.

The interview results also provide insights into the relationship between patient and caregiver. The qualitative analysis of the interviews confirms competence, integrity, benevolence as trust dimensions (Mayer et al., 1995) and identified communication skills as an additional dimension of trust building for caregivers. The results confirm the research model, but emphasise communication as an influencing factor more than was initially assumed.

When reflecting upon what can be learned from our results regarding technological enhancements and how they affect trusting beliefs within a social environment, we conclude that perceptions of human traits, as well as the technology, are both likely to be main factors. As positive and negative experiences mentioned by patients were mainly related to information and communication, we intend to conduct further research focused on encounters with caregivers and patients in the field. We would like to compare how smart glasses change such encounters.

We intend to use media naturalness theory as a guiding theory for our future work. Media naturalness theory builds upon the theory of evolution by Charles Darwin (Darwin, 1859) and proposes that humans have evolved using ‘natural’ communication and are therefore genetically optimised for certain communication traits (Kock, 2009). Natural communication encompasses facial expressions, body language, speech, synchronicity and co-location of communication partners (DeRosa, Hantula, Kock and D’Arcy, 2004). Using different smart glasses designs we intend to test the influence of facial expressions on the naturalness of the communication between caregivers and patients. Since facial expressions increase the naturalness of communications we hypothesise:

H1: Smart glasses’ designs that obscure facial expressions will be perceived as less natural than face-to-face communication.

Technology interaction by the caregiver with the smart glasses could be done using voice commands or body language. Using body language like hand gestures will likely have an influence upon the naturalness of the body language of the caregiver. Moreover, voice commands will probably have an influence on the naturalness of the vocal communication (speech) between caregiver and patient. Therefore we hypothesise:

H2: Technology interaction with smart glasses that uses body language will be perceived as less natural than face-to-face communication.

H3: Technology interaction with smart glasses that uses voice commands will be perceived as less natural than face-to-face communication.

We intend to conduct a series of experiments in which we manipulate the factors described above in order to test our hypotheses.

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Smart Glasses in Health Care: A Patient Trust Perspective

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Abstract

Digitization in the health care sector is striving forward. Wearable technologies like smart glasses are being evaluated for providing hands-free and septic-safe access to information systems at the point of care. While smart glasses hold the potential to make service processes more efficient and effective, it is unclear whether patients would opt-in to treatments involving smart glasses. Patients are not active users of smart glasses but are nevertheless affected of outcomes produced by the symbiosis of health care workers and smart glasses. Using an online survey with 437 respondents, we find that it is important to properly explain to patients why smart glasses are being used and to proactively address data privacy concerns. Otherwise, smart glasses can significantly increase risk perceptions, reduce patients' estimates of health care workers' abilities, and decrease patients' willingness to opt-in to medical procedures.

1. Introduction

Patients value time with their medical personnel. They want to know details about their health status and wish for a warm and trusting relationship with the people who are looking after them. The central role of interaction quality for evoking patient satisfaction has been recognized by numerous studies [1]. High-quality care can only be achieved through a good relationship between patient and caregiver [2]. However, as more and more time in health care is being spent on administrative tasks, there is less time for direct patient care [3]. Health care workers spend large portions of their shifts reading and documenting patient data on computer monitors or paper. As a result, health care personnel frequently experiences a lack of time for direct patient care, which can negatively affect interaction quality and thus patient satisfaction.

Over the last years, various portable devices have been developed for a variety of purposes and applications [4]. Wearable Information- and Communication Technology (ICT) like Augmented Reality (AR) smart glasses are a promising emerging technology that may have the potential to transform health care processes and health management in general. AR smart glasses augment reality with virtual information [5] and could be used to complement or enhance service processes and workflows at the Point of Care (POC) while working hands-free. They could be used to lessen administrative burdens by providing information access at the POC and by documenting procedures while health care workers perform them. Finally, smart glasses could be a vehicle for integrating artificial intelligence engines in daily clinical practice [6].

Some studies suggest that smart glasses can improve processes in domains without direct customer involvement like maintenance and logistics [7]. In the health care sector, smart glasses have been adopted with several useful applications including, hands-free photo and video documentation, telemedicine, Electronic Health Record retrieval and input, rapid diagnostic test analysis, education, and live broadcasting [8-10].

Despite their potential, research on the usage of smart glasses in the health care sector is still at a very early stage and studies taking both, the patient and the health care worker's perspective are scarce [2]. A study by Prochaska et al. found that many patients had concerns about privacy, but very few expressed that it would affect their trust in a doctor [11].

It is easy to imagine that smart glasses might have negative side effects on patient trust and interaction quality. Smart glasses can obscure parts of the health care worker's face or divert attention from the patient, which could negatively impact communication. Furthermore, most smart glasses have outward-facing cameras that are directed at the patient. This might raise privacy concerns on the patient's side, impeding overall acceptance of the technology.

The research question targeted by this work is thus: *How does health care workers' use of smart glasses affect trusting beliefs of patients*?

In order to answer this question we take an in-depth look at how the use of smart glasses in health care would affect the relationship between medical personnel and patients. Building upon interpersonal trust literature, we develop a research model explaining the patient perspective regarding the use of smart glasses in health care settings. We have empirically tested the research model with a survey.

2. Background

In this section, we will summarize related work on trust and smart glasses in the health care sector. In general, trust is defined as a latent variable made up of different dimensions [12]. In this work we define trust according to the definition of Mayer, Davis, and Schoorman [13] (page 724): "Trust is the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" [13].

2.1. Trust in person

One large stream of research in the IS literature has focused on trust between people or between groups [14]. Trustors decide to trust a trustee based on their perceptions of the trustee's abilities, benevolence and integrity [13]. Trust perceptions are also moderated by the trustor's disposition to trust. Whether a trustor decides to be vulnerable to another party or not, depends on his risk perceptions and how much he trusts the trustee [13]. While the main focus of the IS community has been on virtual teams and online markets [14], trust-related research pertaining to professionals in the health care sector also exists.

Patients strive to gain control over their illnesses. Research indicates, that patients perceive contacting medical experts as the most effective means to cope with illness, to reduce uncertainty, and to deal with anxiety [15]. Patients want caregivers to be genuine, not in a hurry, available and willing to talk to them [16]. Patients' willingness to opt-in to a medical procedure depends to a large part on how the procedure is described to them by the medical personnel [17]. There is a general consensus in the nursing field that effective communication with patients is integral to good practice. Trust in the health care provider has been found to correlate positively with adherence to treatment, provider continuity, and perceived effectiveness of care [18]

Nonverbal communication between health care professionals and patients also takes a crucial role in building patients' trust [19]. Nonverbal communication consists of social cues like eye contact, body posture, and facial expressions. Research has shown that consistent eye contact with patients leads to stronger trust, while forward-leaning body posture and smiling did not influence trust [19].

2.2. Passive trust

According to Montague and Xu, a passive user is defined as an individual with limited control over the technologies and IT artifacts used in a system [20]. Nevertheless, passive users are directly affected by the results and the outcome of technology use. A passive user can observe the actions and interactions of the active user with the technology. Moreover, the passive user is influenced by outcomes produced by the technology and the active user. A communication of the passive user with the system is only conditionally possible, or is moderated by the active user. Although passive trust has been mentioned in various contexts, little empirical research on this topic can be found [21]. Moreover, passive trust has not been integrated with and delimited by existing trust research.

Very little IS research has focused on the passive user perspective. This finding is supported by Söllner et al., who find that IS research on trust has mainly focused on the trust relationship between the user and the information system itself, largely neglecting that other targets of trust might also drive IS use from a user's point of view [22]. Transferred to the medical context, patients are passive users of medical technologies, while physicians and caregivers are active users.

2.3. Smart Glasses

Smart glasses are a new generation of wearable devices that have the potential to transform healthcare processes and healthcare management in general [23, 24]. Their main advantage is that they can be operated hands-free, thus allowing healthcare workers to use both hands for their work while having access to an information system [9, 25, 26].

It is relevant to passive users to have a rough idea of the active user's actions with a smart glass [27]. This perspective roughly aligns with findings from the technology acceptance literature. While the technology acceptance literature assumes an active user perspective, perceived usefulness has been identified as a key driver for technology acceptance [28]. A study conducted by Weiz et al. indicates that the link between perceived usefulness and actual use is likely to be present in the context of smart glasses [29].

Not much research has been done to understand how smart glasses are being perceived by onlookers [30]. Given the insights into the value of verbal and non-verbal communication in health care for building trust, the question arises how smart glasses would impact communication behaviors between health care workers and patients.

Extant research shows that smart glasses may disturb, disrupt, alter [31], or impair social interaction [32] and thus, may call for a new social etiquette. Smart glass usage is perceived critically, but more positively from a first-person perspective (the user herself) than from a second-person perspective [27]. Data privacy concerns are often voiced with regards to smart glasses privacy and can strongly influence users' decision making [33]. Moreover, it is preconceived that smart glasses are always recording [27]. General mistrust in technology manifests itself in behaviors such as laptop users blocking the integrated webcam with Post-its [23]. Hein et al. came to the conclusion that when it comes to smart glasses, people tend to care more about other people's privacy than about their own [23].

3. Research Method

Passive trust is inherently linked to both, interpersonal trust and trust in technology. The constructs and models for interpersonal trust are well established.

3.1 Research Model

Within our research model, we build upon Mayer's model of interpersonal trust [13]. The research model we developed is depicted in Figure 1. The constructs and arrows drawn in black are adapted from Mayer's model, while hypothesized additions are colored in blue.

As described in the last section, data privacy concerns and perceived usefulness are likely to play a role in the passive trust context. Therefore we incorporated these two factors into our research model and expect them to influence both, trust in the caregiver and opt-in intentions.

A substantial body of literature has shown that trust influences perceptions of perceived usefulness [34]. Thus we hypothesize that patients who trust their caregiver will be more likely to perceive the use of smart glasses as useful (h1).

Furthermore, the technology acceptance model proposes that perceived usefulness predicts behavioral intentions [28]. Behavioral intentions are conceptually very similar to opt-in intentions. Thus we hypothesize that patients who perceive the use of smart glasses in health care to be useful will be more likely to opt-in to medical procedures (h2).

Regarding privacy perceptions, relationships can be inferred from the Privacy–Trust–Behavioral Intention model [35]. It poses that privacy is an antecedent for trust, which in turn predicts behavioral intention. Building upon this model, we expect individuals that hold privacy concerns regarding the use of smart glasses to trust caregivers less (h3).

The second implication of this model is that patients with privacy concerns should also to be less inclined to opt-in to medical procedures involving the use of smart glasses (h4).

3.2 Study Design

In order to test our research model and to gain a better understanding of how passive trust works, we used an online survey with two treatments employing a between-subject design.

The online survey was implemented using the limesurvey software. It randomly assigned participants to one of two treatments. One of the treatments was a control treatment without smart glasses, while the other was an experimental manipulation treatment. The main difference between the manipulation and control treatment was the description of a scenario. In the manipulation treatment, smart glasses were used to perform a medical procedure, while there were no smart glasses used in the control treatment.

3.3 Scenario description

The text used to describe the scenarios in control and manipulation group were nearly identical. A scenario was described, in which the reader takes a patient's perspective. The patient is lying in a hospital bed and is recovering from an operation. A caregiver enters the room, removes the bandages covering the surgical wound on the left forearm and measures the size of the wound. In total, four pictures of the caregiver performing different actions are provided to make the scenario more vivid.

In the manipulation group, only one short sentence was added that states that smart glasses are currently

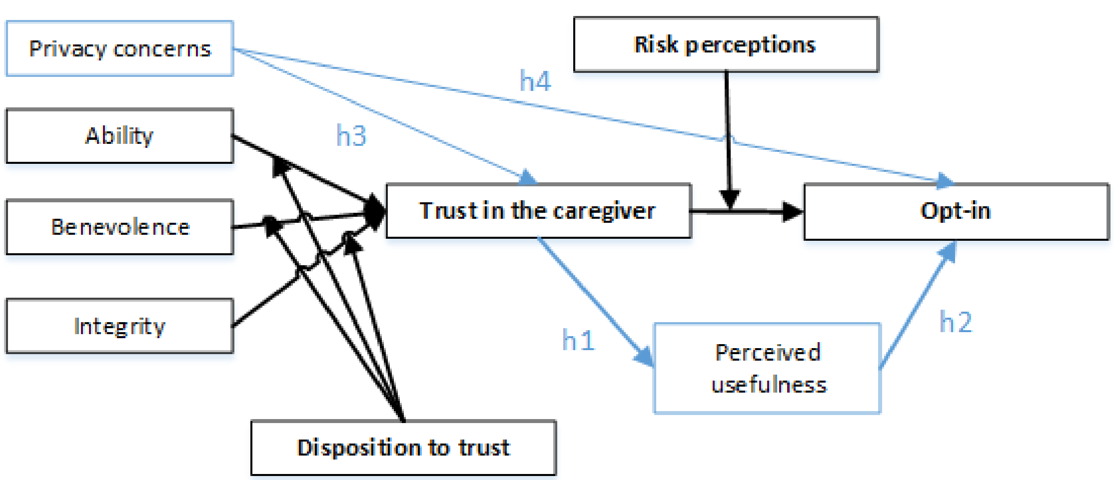

Figure 1: Research model

being tested by the nursing staff of the hospital. Moreover, on each of the four pictures in the manipulation scenario, the caregiver is wearing smart glasses. The pictures in the control group show the caregiver performing the same actions as in the manipulation scenario but without wearing smart glasses. Figure 2 shows an example of the differences between the pictures employed in the control and manipulation groups.

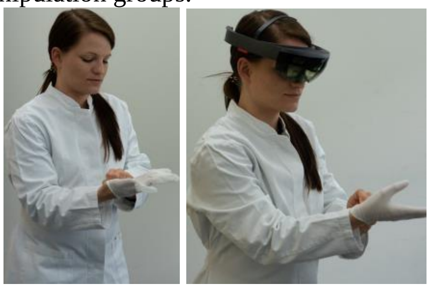

Figure 2: Differences between control and manipulation group. (Left picture: Control group; Right picture: Manipulation group)

3.4 Data collection

Participants for the survey were recruited using advertisement on Facebook. We designed an advertisement that asked Facebook users to support one of the author's dissertation project by participating in an online survey about "trust in the health care system".

In order to gather patient perceptions regarding use of smart glasses in health care, we used several constructs that have been developed and validated in prior studies. Wherever necessary, item wording was adapted to the context of this research study. Items for which no German translation could be found in the scientific literature were translated to German using the method described by Brislin et al. [36].

We were not able to find a validated construct for patient opt-in that we deemed appropriate for the context of our study. Therefore we developed items for this construct ourselves. We checked for content validity by testing the items with two researchers trained in scale development. The factor analysis which is presented in the results section of this paper suggests that our construct has good discriminant validity from the other constructs used in this study.

All items and constructs that were used in the online survey are listed in table 1. The constructs "privacy" and "perceived usefulness" were not used in the control scenario, because their wording is focused on a technology supporting a process. Survey participants were also asked to provide their age, gender and whether they had received surgery before. We also included a control question to assert that survey participants were actually reading the questions.

Table 1: Measurement items
(7-point Likert scales from strongly agree to strongly disagree)
German translations can be provided upon request

Constuct	Item	Loading
Opt-in (self-devel-oped)	I would not have any objections to this treatment.	0.945
	I would consent to this treatment.	0.954
	I would not voice any concerns about this treatment.	0.887
Disposition to trust [37]	I generally trust other people.	0.862
	I generally count on other people.	0.881
	I generally have faith in humanity.	0.815
Ability [38]	The caregiver is competent.	0.862
	The caregiver understands the profession she works in.	0.904
	The caregiver knows how to provide excellent service.	0.841
	The caregiver knows about nursing.	0.920
Bene-volence [38]	I expect I can count on the caregiver to consider how its actions affect me.	0.783
	I expect that the caregiver's intentions are benevolent.	0.807
	I expect that the caregiver puts patients' interests before their own.	0.725
	I expect that the caregiver is well meaning.	0.833
Integrity [38]	Promises made by the caregiver are likely to be reliable.	0.863
	I expect that the caregiver will keep promises she makes.	0.813
	I do not doubt the honesty of the caregiver.	0.726
	I expect that the advice given by the caregiver is their best judgment.	0.820
Risk [39]	It would be risky to disclose my personal health information to health care providers.	0.805
	There would be high potential for loss associated with disclosing my personal health information to health care providers.	0.900
	There would be too much uncertainty associated with giving my personal health information to health care providers.	0.969
	Providing health care providers with my personal health information would involve many unexpected problems.	0.933
Trust [40]	I trust the caregiver to be reliable.	0.854
	I believe the caregiver to be trustworthy.	0.922
	I trust the caregiver.	0.941
Perceived Usefull-ness [41]	Using smart glasses enables the caregiver to complete her daily tasks faster.	0.787
	Using smart glasses improves the productivity of the caregiver at her tasks.	0.958
	Using smart glasses can increase the caregiver's productivity at work.	0.953
Privacy [41]	I feel safe to store private data in the smart glasses.	0.948
	The storage of sensitive data on the smart glasses would worry me.	0.728
	The use of smart glasses negatively affects my privacy.	0.850

3.5 Participants

Overall, we received 918 responses to our online survey. However, several answers needed to be filtered out, because participants gave incorrect answers to the control question (115 instances) or did not complete the survey (438 instances).

This left us with a total of 437 valid responses to our survey (manipulation: 222 (= 50.8%), control 215 (49.2%)). 69 participants (15.8%) were male and 368 (84.2%) were female. The average age was M = 45.12

years (SD = 13.93). Overall 387 (88.6%) stated that they have received surgery in the past.

The manipulation group (n = 222) was comprised of 42 males (18.9%) and 180 females (81.1%). The average age in the manipulation group was M = 45.2 years (SD = 13.87). The control group (n = 215) consisted of 27 males (12.6%) and 188 females (87.4%). The average age was M = 45.0 years (SD = 14.01).

4. Analysis

We used IBM SPSS Statistics (25.0) to conduct a descriptive statistical analysis. In addition, SmartPLS 3.0 was used to test the overall structural model and to determine the factor loadings as depicted in table 1.

4.1. Reliability analysis

Focusing on the newly developed construct "Opt-in", its Cronbach's alpha value is 0.954, indicating a reasonable internal consistency. In addition, this value did not significantly increase when one of its three items was deleted.

Further, construct reliability was assessed by calculating the composite reliability and average variance extracted for "Opt-in" based on the loadings from Table 1. Composite reliability equals to 0.943 and thereby exceeds the minimum threshold of 0.7. Average variance extracted results in 0.847 and thereby exceeds the minimum threshold of 0.5 as well. All other constructs employed in this study also exceeded the minimum threshold for Cronbach's alpha.

4.2. Quantitative Results

We employed three quantitative approaches to analyze the survey results.

4.2.1. Partial Least Squares SEM. In order to test the hypotheses h1-h4, as well as the path coefficients for the overall model, partial least squares path modeling (PLS-PM) was applied using the data of the manipulation group (n = 222).

In order to compute the path coefficients, a consistent PLS algorithm was used to correct for reflective constructs' correlations. Bootstrapping with 2000 samples was used to test whether coefficients such as outer weights, outer loadings and path coefficients are significant by estimating standard errors for the estimates.

The resulting standardized coefficients, as well as their significance levels, are depicted in figure 3. Age and gender were included as independent variables to control for their effects. Regarding the overall model fit the SRMR (= 0.070) is lower than the suggested threshold [42]. The adjusted R square equals 0.657.

We find hypotheses 1, 2 and 4 to be confirmed, while hypothesis 3 was not confirmed. Trust in the caregiver increases perceived usefulness and opt-in intentions, while privacy concerns regarding smart glasses negatively affect opt-in intentions.

Moreover, most aspects of the interpersonal parts of our research model are roughly in line with the results from Mayer et al [13]. Ability, benevolence, and integrity are strong predictors for trust in the caregiver and trust in the caregiver has a positive effect on opt-in intentions. Interestingly, risk perceptions did not have a moderating influence in our study, as described by Mayer et al. [13] and disposition to trust only moderated the relation between integrity and trust.

4.2.2 Mediator and Moderator analysis. Next, we conducted a mediator and moderator analysis for factor combinations involving perceived usefulness and privacy concerns. While we did not find any moderation effects, we found that the relationship between trust in the caregiver and opt-in intention is

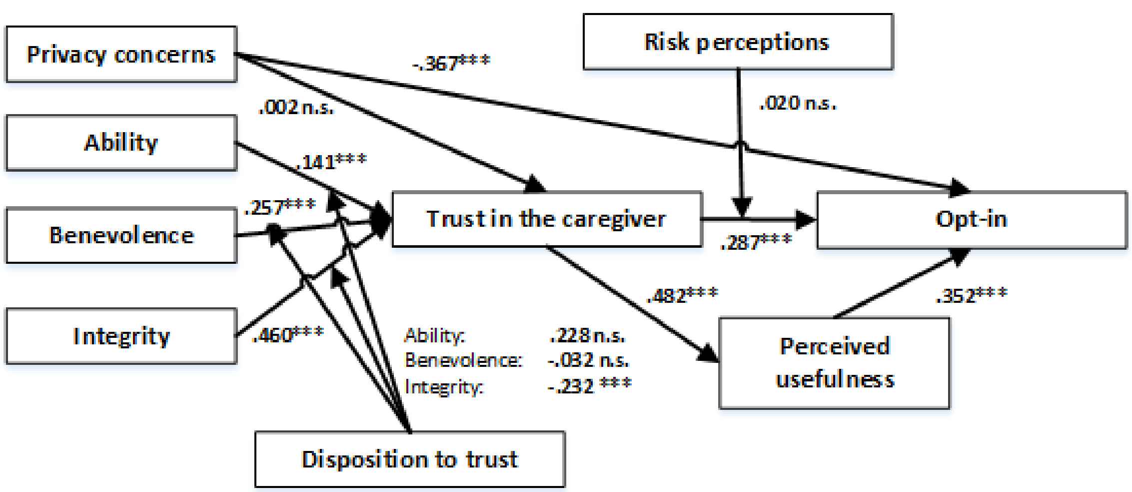

Figure 3: Standardized coefficients
(p-value significance level: *.05, **.01, *.001)**

partially mediated by perceived usefulness (indirect effect ab = .160, 95%-CI[.096, .221]).

4.2.3 Comparisons between manipulation and control group. To test differences between the two treatments, contrast tests based on the Wilcoxon signed-rank test were used [43]. All significant results (p < .05) of the contrast tests are reported in the "Comparison"-column of Table 2. In addition, Table 2 also reports means and variances. Data associated with trust, technology acceptance and privacy outcomes were analyzed using an ANOVA test on the two between-subject factors as independent variables: The manipulation treatment (1) shows pictures of a caregiver wearing a smart glass, while the control treatment (2) uses the same scenario description but shows pictures of the caregiver without smart glasses.

Table 2: Survey results
(p-value significance level: *.05, **.01, *.001)**

Outcomes	(1) Manipulation		(2) Control		Comparison
	M	SD	M	SD	
Opt-in	4.46	1.79	5.05	1.66	1<2***
Propensity to trust	3.25	1.39	3.39	1.32	No significant effects
Ability	4.44	1.27	4.71	1.40	1<2*
Bene-volence	4.67	1.20	4.86	1.20	No significant effects
Integrity	4.79	1.04	4.91	1.01	No significant effects
Risk	3.91	1.60	3.38	1.45	1>2***
Trust	4.88	1.21	4.92	1.22	No significant effects

4.2.4 Effects of age and gender. Within the manipulation group we checked whether age and gender had an effect on any of the measured constructs. Table 3 lists all constructs that significantly correlated with age in our manipulation group. Age was significantly negatively correlated with the disposition to trust humans as well as the benevolence, integrity and overall trust in the caregiver.

Table 3: Influence of age
(Effect sizes are calculated using spearman's rho. P-value significance level: *.05, **.01, *.001)**

	Disposition to trust	Benevolence	Integrity	Trust in caregiver
Effect size	-.23***	-.23***	-.14*	-.14*

All constructs of the manipulation group that significantly differed between male and female participants are listed in Table 4. Overall, females reported higher risk perceptions and privacy concerns, while perceiving smart glasses to be less useful and being less willing to opt-in to medical procedures involving smart glasses than men.

Table 4: Gender differences
(Calculated using Wilcoxon signed-rank test. P-value significance level: *.05, **.01, *.001)**

	Opt-in	Perceived usefulness	Risk perceptions	Privacy concerns
Effect size	-.49***	-.25*	-.31**	-.33*

4.3. Qualitative Results

Participants of the survey also had the option to elaborate their opinions in an open comment text field at the end of the survey. We clustered the qualitative comments into categories and will present them in the following. The number in brackets behind each category indicates the number of comments per category.

4.3.1 The scenario presented in the survey (26 comments). Most comments in this category focused on how the actions of the caregiver were perceived. For instance, some people found that the caregiver did not display a lot of empathy. They would have expected the caregiver to ask follow-up questions about the pain the patient was suffering. Moreover, some participants noticed that the caregiver did not disinfect her hands at the beginning of the procedure. Some participants would have preferred the presence of a doctor to check the wound.

4.3.1 Smart glasses (17 comments). The positive comments on the smart glasses focused on the reduction of errors, higher productivity, and suggestions for other use cases in health care. There were also negative comments about smart glasses. Some survey participants found that caregivers wearing smart glasses look inhuman. Especially because it is difficult to see the caregiver's eyes. Some comments suggest that survey participants would find it difficult to build a trusting relationship with a person wearing smart glasses.

4.3.1 Eye contact (12 comments). Patients find eye contact important to assess the caregiver's trustworthiness. Some survey participants perceived smart glasses as a communication barrier. Some comments imply that patients perceive the use of smart glasses as a tradeoff between process efficiency and an emphasis on personal contact during care.

4.3.1 Data security (10 comments). Patients voiced concerns about the misuse of their medical data. They would not like their medical insurance to have access to data that was recorded during their hospital stay. There were also positive comments which mentioned that smart glasses might be able to prevent others from seeing confidential information.

6. Discussion

Our results have unveiled several insights into the inner workings of passive trust in the health care sector. The empirical results show that perceived usefulness and privacy concerns are important factors regarding smart glasses, trust in caregivers and opt-in intentions. As expected, a mixture of interpersonal trust and technological aspects play a role in explaining opt-in intentions. This conclusion is highlighted by the mediating effect of perceived usefulness on trust in the caregiver and opt-in intentions.

We can quantitatively confirm results reported in other studies regarding gender and smart glasses. Koelle et al found that females are more likely to express negative feelings about the use of smart glasses [27]. In our study, female participants viewed the use of smart glasses significantly more negatively than male participants in some dimensions. Females reported significantly higher risk perceptions and privacy concerns regarding the use of smart glasses in the presented scenario than the male participants. Furthermore, females perceived the smart glasses to be less useful and were less willing to opt-in to procedures involving smart glasses than men.

Interestingly our findings regarding age differ with the results reported by other studies in which older patients are generally more inclined to trust [19]. In our study, age was negatively correlated with the disposition to trust and trust in the caregiver, which was presented in the scenario. Moreover, older participants rated the benevolence and integrity significantly lower than younger participants. Interestingly, none of these factors are technology-related. Instead, they are all clustered on an interpersonal level.

When reflecting upon these results one should keep in mind that we used Facebook as a recruiting tool. Thus the oldest participant in our study was 74 years old, and our sample does not represent the age group of 70 and older. Next, this study took place in the health care context. In the comments section of our survey, we received many individual case descriptions of instances in which participants experienced something that made them loose trust in the health care system. It is possible that older patients have more experience with the health care system and are thus more likely to have experienced something negative.

6.1. Practical implications

We purposefully did not provide a detailed explanation of how smart glasses work to the participants of the study. We did this in order to maximize the consistency of our study by keeping it as similar as possible to the control scenario. Moreover, Angst et al. have already shown that patients' willingness to opt-in to a medical procedure depends to a large part on how the procedure is described to them by the medical personnel [17]. The focus of our study was therefore to gather insights into patients' initial perceptions of smart glasses.

Our results show that privacy concerns regarding smart glasses should be taken seriously. When using smart glasses in a professional environment like health care, efforts should be undertaken to increase the perceived usefulness of passive users and to decrease privacy concerns. We recommend providing informational material on what data is being gathered and why the smart glasses are of value. For instance, videos that describe use case scenarios and show the caregiver's perspective using smart glasses could be helpful. As females report higher levels of privacy concerns, it might be a good idea to develop information material that is appealing to them.

6.2. Theoretical contributions

We contribute to theory by conducting exploratory work on passive trust. To the best of our knowledge, only very little research has been conducted on this topic. We think that research in this field is needed, as technology and particularly artificial intelligence are becoming more prevalent in our lives. Scenarios in which individuals are dependent on outcomes produced by a symbiosis of humans and machines will occur more frequently.

The constructs that drive passive trust are still elusive. While several parts of the interpersonal trust literature can be reused for the passive trust context, new constructs need to be developed to account for the technological influences. In our research, we make a first step towards this end by developing an opt-in construct. The reliability characteristics of the newly developed construct are good and it can be reused for passive trust research in other contexts. Moreover, we extend the body of research on passive trust by applying well-established constructs from the IS trust literature to context of passive trust.

Furthermore, we contribute to interpersonal and technological trust research. We extend the interpersonal trust model of Mayer [13] to the context of passive trust and identify constructs that help to model technology perceptions. The empirical results of our study suggest that our research model is able to explain how trust perceptions and opt-in intentions emerge and can thus serve as a conceptual basis for further investigation of passive trust. More specifically, we show that perceived usefulness and privacy concerns are important technological factors for passive trust.

Finally, in the following, we will outline an agenda for future research that can help fellow researchers to advance the theoretical knowledge of passive trust.

6.3. Agenda for future research

Our study has several limitations. Firstly, we have a very unequal gender representation in our sample. 84% of this study's participants were female. Thus, despite being statistically significant, the results pertaining to gender should be regarded with caution and be treated as preliminary results. We hope that future research will be able to shed more light on gender differences by conducting more empirical studies on the use of smart glasses.

Interestingly, privacy concerns regarding smart glasses did not have a negative effect on trust in the caregiver. One explanation for this might be that patients do not think that medical personnel would be inclined to misuse their data. Qualitative research with patients could shed more light on this finding.

While we were able to show that privacy concerns and perceived usefulness are important factors in the context of passive trust, it is quite likely that we have missed other important factors. Several comments suggest that the empathy displayed by the caregiver could be relevant. This would also be in line with prior findings in the medical literature that highlight the role of communication in health care [2]. Furthermore, as disposition to trust did not have the moderating effect that it has in other contexts, further research is needed. Especially our results pertaining to age suggest that a construct regarding overall trust in the healthcare system should be tested in future questionnaires. Testing constructs like trusting stance and propensity to trust which are related to disposition could be a good starting point for this endeavor.

Similar to disposition to trust, risk perceptions did not have the moderating effect we assumed they would. One aspect that could be interesting for future research is to look into how the severity of an illness affects passive trust and opt-in intentions. It is quite possible that opt-in to medical procedures is higher when a patient has a life-threatening disease than when the patient only has a minor illness. Severity is conceptually different to the construct of risk perceptions we used in this study, as it would focus on the health state of the patient instead of risk concerns regarding the use of smart glasses.

The caregiver's abilities were rated significantly worse in the manipulation scenario, than in the control scenario. This is somewhat surprising because in theory the smart glasses should enhance the caregiver's capabilities and improve the capability to provide professional care. It is possible that patients have a specific picture in mind when it comes to judging a caregiver's capabilities. Maybe patients consider empathic treatment and good communication with the patient to be central to the caregiver's job and perceive smart glasses as a barrier to achieving this goal. Future research should take a more in-depth look at this phenomenon. One way to approach this could be to investigate the patient's perceptions of a caregiver's empathy and to evaluate whether empathy correlates with ability perceptions. Another approach could be to compare whether patients deem it more appropriate if doctors use smart glasses than if caregivers do.

This study focused on the use of smart glasses in the health care sector. However, the notion of passive trust is much broader. In order to be able to make generalizations about passive trust in different contexts and technologies, further research is needed. We encourage fellow researchers to conduct empirical research on use cases in other domains and to compare the results to ours.

7. Conclusion

In this research, we have investigated how the use of smart glasses in the health care sector is perceived by patients. Patients are not active users of the smart glasses but are dependent on outcomes produced by caregivers using this technology. Thus both interpersonal and technological aspects play a role in this context.

Building upon interpersonal trust literature we have developed a research model and have tested it empirically using an online survey. As predicted by the interpersonal trust model, the results confirm that ability, benevolence, and integrity predict trust in the caregiver and opt-in intentions to medical procedures. However, risk perceptions and disposition to trust did not have their theorized moderating effects.

Furthermore, we identify patients' perceived usefulness and privacy concerns as relevant factors for modeling technological aspects of smart glasses. Both constructs had strong correlations with trust in caregivers and opt-in intentions.

Age was significantly negatively correlated with several interpersonal constructs. This implies that older people have less trust in caregivers. Female participants had significantly higher risk and privacy concerns than males and were less willing to opt-in to medical procedures involving smart glasses.

Future research on the passive user perspective is needed. The results of our research suggest that several other factors like perceived empathy or severity of the patient's illness could be relevant constructs in the context of passive trust.

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