The Meaningful Use of Cloud Computing in Healthcare

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Outline

List of Abbreviations

DoI Theory	Diffusion of Innovations Theory
HOT-fit Model	Human, Organization and Technology-fit Model
IS	Information systems
IT	Information technology
IaaS	Infrastructure as a service
MI	Medical informatics
MO-MS	Multi-organizational multi-stakeholder
PaaS	Platform as a service
$RQ^{overarching}$	Overarching research question
RQ	Research questions
SaaS	Software as a service
SLMC	Six-Layer Model of Collaboration
TOE Theory	Technology-Organization-Environment Theory

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Preface

This dissertation is composed in a cumulative style.

I would like to thank Prof. Dr. Ali Sunyaev for his supervision of the entire Ph.D. thesis. I would also like to thank Scott Thiebes and Prof. Dr. Robert O. Briggs who are the co-authors of included articles in this dissertation.

My particular thanks go to my wife Jing, my son Zaizai, and my parents, Jianxia and Dongqing, for your support during the last years. Your love has kept me smiling and inspired.

1. Introduction

This dissertation focuses on the meaning of cloud computing for healthcare and its meaningful use in the healthcare industry. The introduction provides an overview of the background and research questions (Section 1.1), conceptual foundation (Section 1.2), theoretical perspective and approach (Section 1.3), included articles (Section 1.4), and their implications (Section 1.5) for this dissertation.

1.1 Study Background and Research Questions

Cloud computing is an innovative paradigm that provides users with on-demand access to a shared pool of configurable computing resources, such as servers, storage, and applications (Mell, Grance 2011). The information technology (IT) services provisioned by cloud computing (i.e., cloud computing services) are web-based and can be rapidly released with minimal management effort. Thus, cloud computing presents "a fundamental change" (p. 176) in how IT services are developed, deployed, maintained, and paid for (Marston et al. 2011). Cloud computing services have the potential to provide various benefits for numerous industries (e.g., Jones et al. 2017; Dahlberg et al. 2017; Chatzithanasis, Michalakelis 2018), including the healthcare industry, which mainly provides care-related goods and services (Meri et al. 2018; Benlian et al. 2018). If used in a meaningful way (i.e., meaningful use: cloud computing provides constructive support; Nelson, Staggers 2018), cloud computing is able to provide major benefits to the healthcare industry. It allows healthcare organizations (i.e., hospitals or clinics) with insufficient IT resources/infrastructure to easily access the required IT services through a network, which is based on a pay-as-you-go pricing model. Furthermore, it enables healthcare organizations with a shortage of health IT staff (which is a general challenge currently in the healthcare industry; Zieger 2017) to deploy IT resources to meet ever-changing medical demands in a timely manner, imposing only a minimal workload on their own IT staff (Kuo 2011). Therefore, researchers argue that cloud computing could serve as a strong enhancement to traditional health IT (Benlian et al. 2018; Kuo 2011). Practitioners have thus recognized the relevance of cloud computing for healthcare, and have called for a massive acceleration of the meaningful use of cloud computing services to support the healthcare industry (Joch 2017; Linthicum 2017).

Evidence from practice has indicated the increased use of cloud computing services by healthcare organizations (e.g., HIMSS 2016; Sturman 2017). Surprisingly, the benefits promised by using cloud computing often do not hold in practice: it has, for example, been reported that the use of cloud computing services is tied to implementation and preparation activities that impede the flexibility of cloud deployment (Sultan 2014). In addition, the promised high availability of cloud-based IT resources cannot always be ensured (e.g., sometimes the maximal attainable IT resources are strictly pre-defined; ZapThink 2013); and the use of cloud computing services is not guaranteed to yield the expected economic advantages for users in healthcare (e.g., due to unexpected high upfront costs; Miah et al. 2017).

Both healthcare organizations and the use of cloud computing are complex phenomena. On the one hand, healthcare organizations are characterized as highly intricate and special because of the operational complexity of medical services (Singh, Wachter 2008), and the healthcare context involves different stakeholders with different interests (Standing, Standing 2008). The healthcare industry is operationally complex and highly institutionalized (Scott 2005); healthcare organizations exist in different forms (e.g., for-profit; not-for-profit; government; private for-profit; private not-for-profit) with different motivations and interests (Chiasson, Davidson 2004) and usually feature a dual administrative system of medical personnel and administration (Chiasson, Davidson 2004). Furthermore, health reimbursement and the related financial resources often depend on external insurers or agencies with their own concerns and agendas (Singh, Wachter 2008). On the other hand, the use of cloud computing is by its nature accompanied by diverse challenges for healthcare organizations, particularly with respect to their management (e.g., difficulties in conducting IT audits), technology (e.g., data transfer bottlenecks), security (e.g., privilege abuse), and legal aspects (e.g., applicable law for service contracts) (Kuo 2011). Thus, the fit between both complex phenomena (i.e., healthcare organizations and the use of cloud computing) is often not self-evident. Without sufficient support, the deployment of cloud computing services in healthcare organizations does not always result in meaningful use, but could lead to countereffects for healthcare (Kuo 2011). As reported in a previous case, an electronic health record system enabled by cloud computing in a UK hospital diverged from people's initial expectations of meaningful use and led to countereffects: it resulted in a £200 million project failure and the hospital's inability to deliver key services on a large scale (Mathieson 2015; Moore-Colyer 2015).

The topic of cloud computing has attracted a wide range of researchers in the domain of healthcare. Two major streams of existing literature can be observed in research. The first stream has focused on the data security and/or privacy challenges for the use of cloud computing in healthcare. For example, Pinheiro et al. (2018) propose an architecture based on diverse encryption concepts for monitoring health-related data stored in the cloud and the service provider behavior to ensure cloud data integrity and privacy in healthcare. Cheng et al. (2017) develop an innovative authentication scheme working against key compromise impersonation attacks to ensure user anonymity and message authentication for cloud-based telemedicine systems, while Sahi et al. (2016) concentrate on security and privacy preserving approaches and propose a disaster recovery strategy for the use of cloud computing services in healthcare. More generally, studies such as Datta et al. (2016), Deng et al. (2009), and Rodrigues et al. (2013) discuss requirements of security and privacy for the use of cloud computing in different healthcare settings.

The second stream of literature concerns the implementation of cloud computing services that support healthcare, which are more related to the study background of this dissertation. This stream is combined with those of different (emerging) IT phenomena, such as big data (e.g., Zhang et al. 2017), mobile technologies (e.g., Peddi et al. 2017), blockchain (e.g., Liang et al. 2017), the Internet of Things (e.g., Hossain, Muhammad 2016), and gamification (e.g., Fotopoulos et al. 2016). Moreover, the discussed cloud computing services cover a wide range of information systems in healthcare, including telemedicine/teleconsultation systems (e.g., Yu et al. 2013), electronic health/medical record systems (e.g., Bahga, Madisetti 2013), medical imaging systems (e.g., Silva et al. 2012), public health systems (e.g., Botts et al. 2011), hospital management systems (e.g., Yao et al. 2014), and clinical information systems (e.g., Ratnam et al. 2014). Although studies in the second stream cover a wide range of domains in healthcare, they often do not explain the way in which cloud computing could support healthcare in a systematic manner. As proved by Griebel et al. (2015), current health IT studies have proposed cloud computing services in a somewhat blind manner (i.e., without systematically understanding the characteristics of cloud computing for healthcare), and some researchers target cloud computing "just because cloud computing is a current buzzword" (p. 13). It is therefore not surprising that cloud computing services from most studies in the second stream cannot go beyond the conceptual design or prototype stage, and those studies can hardly confirm or evidence heir meaningful use by healthcare organizations (Griebel et al. 2015).

In reply to the aforementioned insufficiency in the research, this dissertation aims to investigate the phenomenon of cloud computing in healthcare organizations and to answer the following overarching research question ($RQ^{overarching}$):

$RQ^{overarching}$: *How can cloud computing support healthcare organizations in a meaningful way (i.e., meaningful use)?*

This overarching research question possesses high relevance for information systems (IS) research due to the following reasons. First, the phenomenon of cloud computing deserves high attention by the IS community. According to Mell, Grance (2011), the most acknowledged definition in the domain of IS, service models and essential characteristics of cloud computing (see the next section for a detailed description) differentiate cloud computing from any other existing IT artefact. The cloud computing concept has therefore established itself in research (e.g., Whitley et al. 2013). Dedicated research journals, such as IEEE Transactions on Cloud Computing, the Journal of Cloud Computing, and the International Journal of Cloud Computing, have emerged to discuss this unique IT artifact, which reflects the value of this phenomenon for research. In addition, cloud computing serves as a typical IT innovation and a type of IT outsourcing in the context of healthcare mainly because IT services enabled by cloud computing are in sharp contrast to traditional IT patterns and are provided by external IT providers (see the next section). Thus, research studies focusing on the meaningful use of cloud computing in healthcare are able to inform IS literature about the IT outsourcing and IT innovations, which belong to major research streams in IS (Jeyaraj et al. 2006; Lacity et al. 2010). Second, focusing on healthcare contexts provides opportunities for the further development or improvement of IS theories. As demonstrated above, the healthcare industry features a complex and specific context that is markedly different than most of other industries, in which IS research is conducted (e.g., manufacturing; financial services) (Chiasson, Davidson 2004). Thus, the use of IT in the healthcare industry possesses unique features and creates special obstacles, and research that pays special attention to this context could advance the IS community's knowledge, and challenge and further refine IS theories (Hong et al. 2014; Johns 2006; Chiasson, Davidson 2005). Consequently, high-ranking IS journals have called for more IS studies in healthcare contexts to devote themselves to theory development for the community (Romanow et al. 2012). This is, in particular, because many previous health IT studies did not pay special attention to healthcare contexts nor leverage their results to advance theory development in IS (Chiasson, Davidson 2005; Romanow et al. 2012). To summarize, addressing the overarching research question in this dissertation could deepen our understanding of the use of IT artefacts that advances IS theories, not only regarding cloud computing itself but also in terms of broader IT innovation and/or IT outsourcing levels.

Study #	Title	Research question(s)	Main purposes
1	Rethinking the meaning of cloud computing for health care: a taxonomic perspective and future research directions	• What are the relevant properties of cloud computing for service delivery to healthcare? • What are the specific meanings of these properties for healthcare?	• To develop a taxonomy that serves as a fundamental mechanism to conceptualize the relevant properties of cloud computing for service delivery to healthcare organizations • To highlight the specific meanings of cloud computing for healthcare and suggest related research directions
2	Context matters: a review of the determinant factors in the decision to adopt cloud computing in healthcare	• What factors influence decisions to use cloud computing (i.e., cloud computing adoption decisions) in healthcare organizations? • How do these factors influence the cloud computing adoption decision? • What specificities do these factors have regarding the healthcare industry?	• To investigate determinant factors of cloud computing adoption decision in healthcare organizations • To derive those factors' influences for the cloud computing adoption decision • To determine industrial specificities of those determinant factors and propose a conceptual model of cloud computing adoption studies in healthcare
3	Exploring cloudy collaboration in healthcare: an evaluation framework of cloud computing services for hospitals	• How do cloud computing services support collaborative activities in healthcare (e.g., medical diagnosis; treatment)?	• To identify relevant aspects of cloud computing services that support collaboration in healthcare • To propose an evaluation framework based on those relevant aspects that can be used to assess existing cloud computing services regarding their capabilities to support collaboration in healthcare
4	Multi-organizational multi-stakeholder collaboration systems: an exploratory research study of design concerns	• What are the design concerns for collaborative health information systems, and which of those aspects can be generalized across multi-organizational multi-stakeholder contexts?	• To discover collaboration challenges in healthcare that are presented by cloud-based and in-house IT services for healthcare • To derive a typology of design concerns and requirements-elicitation design questions related to multi-organizational multi-stakeholder collaboration

Table 1 Content overview of included studies in this dissertation

To answer the defined research question, four research studies were conducted in this dissertation. Table 1 provides a short content overview of the four studies, including their titles, research questions, and main purposes. More detailed descriptions of the studies can be found in Sections 1.3 and 1.4. It is emphasized that, although each research study possesses its own stand-alone research question(s), RQ[overarching] leads the conduction of all four studies.

Table 2 delivers further information about the studies' authors and outlets. The author of this dissertation (Fangjian Gao) is the first author of all four studies. Study 2 has two authors (Fangjian Gao, and Ali Sunyaev), while study 1 and study 3 have three authors (Fangjian Gao, Scott Thiebes, and Ali Sunyaev), and study 4 has four authors (Fangjian Gao, Robert O. Briggs, Scott Thiebes, and Ali Sunyaev). For all four studies, Fangjian Gao provided the research ideas, was responsible for the preparation and conduction of the studies, including data collection and data analysis, and for writing the resulting papers. The co-authors supported the writing of the papers. For study 1, study 3 and study 4, Scott Thiebes supported the data analysis and conducted multiple discussions with the author of this dissertation to develop the papers. For study 2, Jingjiao Jiang, Christian Mascarella, Simon Pütz, Nirujan Indirakumara, and Martin Bölter supported the validating of the coding of articles.

Study #	Authors	Outlet
1	Fangjian Gao, Scott Thiebes, & Ali Sunyaev	Published in Journal of Medical Internet Research (JMIR), 2018
2	Fangjian Gao, & Ali Sunyaev	Under review (1st round) in International Journal of Information Management (IJIM)
3	Fangjian Gao, Scott Thiebes, & Ali Sunyaev	Published in Proceedings of the Hawaii International Conference on System Sciences (HICSS), 2016
4	Fangjian Gao, Robert O. Briggs, Scott Thiebes, & Ali Sunyaev	Submitted to HICSS; final version targets Journal of Management Information Systems (JMIS)

Table 2 Bibliographical overview of included studies in this dissertation

1.2 Conceptual Foundation

Cloud computing in healthcare serves as the conceptual foundation for this dissertation. Section 1.2.1 compares health IT and cloud computing concepts and presents the definition of cloud computing. Subsequently, Section 1.2.2 demonstrates two conceptual perspectives of cloud computing in healthcare environments that guide the application of the concept "cloud computing" in this dissertation.

1.2.1 Cloud Computing and Health IT

According to Mell, Grance (2011), cloud computing is an innovative paradigm that provides users with on-demand access to a shared pool of configurable computing resources, such as servers, storage, and applications. Unlike traditional health IT approaches, in which healthcare organizations make or buy and maintain in-house software applications and hardware infrastructures, cloud computing enables (remote) users to access the required IT services (e.g., software or computing resources) through a network, which is based on a pay-as-you-go pricing model.

Traditional health IT approaches are often insufficient to fulfill the ever-changing and increasing needs in healthcare. Healthcare organizations, particularly in rural areas, often struggle with a scarcity of IT resources, such as computing or storage capacity (Mason et al. 2017). Insufficient off-site access to or inflexible deployment of in-house IT infrastructure restricts healthcare organizations' ability to address the changing IT demands caused by medical emergencies (Adler-Milstein et al. 2017). Furthermore, the time consuming and costly maintenance of existing information systems and shortage of skilled health IT staff make IT a burden for healthcare organizations (Atasoy et al. 2018).

With its unique IT service paradigm, cloud computing can enhance traditional health IT approaches. Cloud computing provides three service models: *infrastructure as a service* (IaaS), *platform as a service* (PaaS), and *software as a service* (SaaS) (Mell, Grance 2011). Cloud computing can deliver either fundamental IT resources (through IaaS), IT platforms with programming languages, tools, and/or libraries for the software development or deployment (through PaaS), or ready-to-use software applications that run on cloud infrastructure (SaaS) to healthcare organizations. Moreover, cloud computing relies on four deployment models (i.e., *public*; *private*; *community*; *hybrid*) to provide IT infrastructure that enables service delivery. In a *public cloud*, the cloud computing service infrastructure is provided for open use by the general public, while the infrastructure of a *private* or *community cloud* is provisioned for the exclusive use of either a single organization or a specific group of organizations. A *hybrid cloud* is a combination of two or more of the aforementioned deployment models. The service paradigm enables cloud computing services to possess five unique essential technical features: *on-demand self-service, resource pooling*, *rapid elasticity*, *broad network access,* and *measured service* (see Table 3). As highlighted in Table 3, these technical features allow cloud computing to alleviate the aforementioned insufficiencies of

Technical feature	Description/Definition	Major value for traditional health IT approaches
On-demand self-service	A cloud user can provide or adjust IT services based on own demand without requiring human interaction with each service provider	To increase healthcare organizations' speed and flexibility in providing unforeseen IT services or resources for emergency events, despite the shortage of skilled IT staff in (rural) healthcare organizations (e.g., Yao et al. 2014)
Broad network access	IT services are available over the network and accessed by diverse client platforms (e.g., PCs; mobile phones; workstations)	To ensure healthcare organizations' ability to gain off-site access to medical data and IT resources (e.g., Reddy, Bhatnagar 2014)
Resource pooling	The cloud provider's computing resources are pooled and can be dynamically assigned to serve a cloud user according to his demand	To increase IT resources and thus overcome a scarcity of computing and storage capacities that threaten health IT operations (e.g., Ratnam et al. 2014)
Rapid elasticity	Capabilities can be elastically increased and released, in certain cases automatically, to scale rapidly outward and inward commensurate with demand	To offer timely, dynamic assignment of healthcare organizations' IT resources based on demand and thus to optimize the use of IT resources and avoid IT bottlenecks (e.g., Ratnam et al. 2014; Ahuja et al. 2012)
Measured service	IT services are automatically used, controlled and monitored by leveraging a metering capability (e.g., a pay-per-use mechanism)	To effectively control IT cost (e.g., Kuo 2011)

Table 3 Unique technical features of cloud computing (Mell, Grance 2011) and their major value for traditional health IT approaches

traditional health IT approaches.

1.2.2 Conceptual Perspectives of Cloud Computing in Healthcare

As mentioned in the introduction, cloud computing is a complex phenomenon in healthcare and thus deserve reflection from different conceptual angles (Nickerson et al. 2013). Relying on previous conceptual understanding of cloud computing, this dissertation considers cloud computing in healthcare organizations from two conceptual perspectives. As demonstrated in this sub-section, both perspectives incorporate 1) *cloud computing as a representative of IT innovation* and 2) *cloud computing as a derivative of IT outsourcing*.

Cloud computing as a representative of IT innovation. An innovation can be defined as an idea, practice, or object that is perceived as new by an individual or group (Rogers 2003). In the context of healthcare, three types of innovation can be observed (Herzlinger 2006): 1) innovations focusing on how consumers buy and use healthcare; 2) innovations applying technology to improve products, services, or care; and 3) innovations generating new business models. By definition, cloud computing is a new practice of applying IT in healthcare organizations (Type 2), because it is in sharp contrast to traditional health IT patterns, as demonstrated above.

Although the concept of cloud computing has existed for nearly ten years (Marinescu 2018), it is still recognized as a highly innovative IT artifact by healthcare organizations (e.g., Gao et al. 2018b; Ozkan 2017; Fernández 2017). This finding is attributable to the specificity of the healthcare industry in the use of IT. Healthcare organizations have been proven to traditionally act as laggards in IT innovation application (Sulaiman, Wickramasinghe 2018; Cicibas, Yildirim 2018). Rogers (2003) explains that such organizations become aware of IT innovation extremely late. Furthermore, it must be stressed that the use of cloud computing services can provide flexible IT infrastructure and thus opportunities for healthcare organizations to apply other sophisticated information technologies. Researchers claim that cloud computing has become the key enabler of digital transformation in the healthcare industry (e.g., Benlian et al. 2018; Bhavnani et al. 2017). Although it is by no means necessary to overvalue the role of cloud computing in healthcare, the essential technical features of cloud computing, particularly *resource pooling*, *rapid elasticity*, and *broad network access* (cf. Table 3), ensure the necessary IT resources and access to different devices. These are basic conditions for the implementation of most IT innovations in healthcare, such as artificial intelligence, big data, and sensor technology. Thus, a very high proportion of existing cloud computing services in healthcare is found to combine with emerging technologies and provides the most innovative IT services to healthcare organizations (e.g., Zhang et al. 2017; Hassan et al. 2017; Liang et al. 2017).

Cloud computing as a derivative of IT outsourcing. Numerous IS studies have explained that cloud computing and IT outsourcing share common characteristics (e.g., Lang et al. 2018). In particular, cloud computing is argued to be similar to application service provision and SaaS of IT outsourcing (Vithayathil 2017; Benlian et al. 2011). IS researchers have compared cloud computing with IT outsourcing and highlighted the similarities between both concepts (e.g., Leimeister et al. 2010).

From the health IT perspective, cloud computing is also regarded as a specific form of IT outsourcing (Hucíková, Babic 2016). In health IT, IT outsourcing refers to the transfer of responsibility for providing IT services to an external provider (Reddy et al. 2008). As demonstrated above, cloud computing has four deployment models: *public*, *private*, *community*, and *hybrid*. Although the *public cloud* is well recognized as IT outsourcing because of its off-premise nature, IT infrastructures of *private* and *community clouds* are often misunderstood as being on the premises of cloud users. Based on Mell, Grance (2011), *private* and *community clouds* may also exist off cloud users' premises, which makes the entire concept of cloud computing more similar to IT outsourcing. It must be stressed that although theorists recommend the use of (partially) on-premise cloud computing services by the healthcare industry for reasons related to data privacy and security issues (Ermakova et al. 2017), few studies have concentrated on the use of cloud computing services with an on-premises IT infrastructure in the healthcare (or other) industry. This is probably because off-premises cloud computing services enable users to utilize their essential technical features to a greater extent (Kilcioglu et al. 2017).

Both perspectives provide a conceptual fundament for and guide the application of the term 'cloud computing' in all four research studies included in this dissertation. In particular, the conceptual perspectives assist in the selection of appropriate theories and/or justify the research design for the studies. Table 4 explains how the conceptual perspectives guide the conduction of all four studies included in this dissertation.

Study #	Applied conceptual perspective(s)	Role of the applied perspective(s)
1	*Cloud computing as a representative of IT innovation*	The applied conceptual perspective observes cloud computing as IT innovation in healthcare. This perspective justifies the selection of Diffusion of Innovations Theory that guides the conduction of study 1 (see Section 1.3 and Table 5).
2	*Cloud computing as a representative of IT innovation & cloud computing as a derivative of IT outsourcing*	The applied conceptual perspectives justify the focus of the data collection and data analysis in study 2: determinant factors that influence IT innovation adoption decisions and IT outsourcing decisions in healthcare that are applicable to cloud computing adoption in healthcare organizations have been investigated and included (see Section 1.3).
3	*Cloud computing as a representative of IT innovation*	The applied conceptual perspective justifies the need for an evaluation tool that improves healthcare organization's knowledge about the use of an innovation.
4	*Cloud computing as a derivative of IT outsourcing*	The applied conceptual perspective observes cloud computing as a preferred form of IT outsourcing by healthcare organizations that complements and improves their in-house IT. Including cloud computing to complement the data of in-house health IT increases the comprehensiveness of the findings of study 4.

Table 4 Overview of the application of two conceptual perspectives of cloud computing in healthcare to the included studies in this dissertation

1.3 Research Design and Theoretical Perspective

In order to answer the research question $RQ^{overarching}$, the author of this dissertation followed Stebbins (2001) to employ *exploratory* approaches to design research studies. This is because, despite the importance of the phenomenon of cloud computing in healthcare, its meaningful use has been unsystematically investigated and is little known (see Section 1.1). Therefore, this dissertation aims to draw on *exploratory* approaches to produce generalizations for the understanding of meaningful use of cloud computing in healthcare (Stebbins 2001). Accordingly, the four studies in this dissertation employ established explorative research methods to explore the meaningful use of cloud computing in healthcare. It is stressed that the four studies leverage knowledge from existing literature and/or expertise from praxis (through expert interviews). This is because *exploratory* approaches should possess "*flexibility* in looking for data and *open-mindedness* about where to find them" (Stebbins 2001, p. 6). Table 5 presents an overview of research design for the four studies in this dissertation.

Study 1 follows an established method in IS by Nickerson et al. (2013) to develop a taxonomy that can be used to classify and analyze cloud computing services for healthcare organizations. The taxonomy development leveraged data from literature and expert interviews to systematically explore properties of existing cloud computing services and their industry-specific meaning for healthcare. It follows the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guidelines* (Moher et al. 2009) to conduct a systematic review of literature about cloud computing services for healthcare organizations. The literature review analyzes 49 research articles from eight highly acknowledged literature databases (see Table 5). In addition, the study follows Flick et al. (2007) to conduct 24 semi-structured interviews with health IT experts from Germany (n=12) and China (n=12). The collected data was analyzed by applying *open coding* technique (Corbin, Strauss 2015), which is inspired by Grounded Theory (Sarker et al. 2001). Based on the coding results, a taxonomy was developed in a *deductive* (i.e., development by analyzing data about conceptual understanding of cloud computing services for healthcare organizations) and an *inductive* manner (i.e., development by observing concrete cloud computing services that need to be classified, namely, data from the empirical category) with 14 iterations.

Study 2 is a literature review that is compliant with the general guidelines for structured literature reviews in IS (Webster, Watson 2002) and in particular applies a data analysis method by Jeyaraj et al. (2006) and Schneider, Sunyaev (2016) to identify determinant factors of cloud computing adoption in healthcare and their specificities for the healthcare industry. Study 2 reviews 43 relevant research studies coming from the most acknowledged academic journals in IS, MI and medicine (cf. Table S.1 in Section 3) and 24 additional relevant articles that have been identified by using forward (i.e., an article has cited at least one of the 43 relevant research studies) and backward (i.e., an article has been cited by at least one of the 43 relevant research studies) searches. Based on both conceptual perspectives of cloud computing in healthcare, study 2 also includes data about determinant factors that influence decision makings for IT innovation adoption and IT outsourcing adoption and are applicable to cloud computing adoption in healthcare. The determinant factors for adoption decision making in healthcare organizations have

Study #	Data sources	Applied research methods	Form(s) of reasoning
1	• 49 research articles from eight literature databases* • Semi-structured interviews with health IT experts from China (n=12) and Germany (n=12)	**Data collection** • The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guidelines** (Moher et al. 2009) • Guidelines for the conduction of semi-structured interviews in qualitative research*** (Flick et al. 2007) **Data analysis** • Grounded Theory-inspired data analysis methods (Corbin, Strauss 2015) **Research results development** • A taxonomy development method in information systems by Nickerson et al. (2013)	*Deductive* and *inductive*
2	• 67 research articles from information systems, medical informatics and medicine outlets	**Data collection** • Structured Literature Review Guidelines in information systems (Webster, Watson 2002) **Data analysis** • Coding methods by Jeyaraj et al. (2006) and Schneider, Sunyaev (2016) **Research results development** • Approach to derive determinant factors for IT adoption by Jeyaraj et al. (2006) and Schneider, Sunyaev (2016) • *Inductive Classification* (Bailey 1994)	*Inductive*
3	• 49 research articles from eight literature databases* • Eleven semi-structured interviews with health IT experts from China	**Data collection** • The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines** (Moher et al. 2009) • Guidelines for the conduction of semi-structured interviews in qualitative research*** (Flick et al. 2007) **Data analysis** • Grounded Theory-inspired data analysis methods (Corbin, Strauss 2015) **Research results development** • A systematic approach to develop evaluation framework for health IT (Corbin, Strauss 2015)	*Deductive* and *inductive*
4	• 100 research articles from eight literature databases* • Semi-structured interviews with health IT experts from China (n=21) and Germany (n=29)	**Data collection** • Structured Literature Review Guidelines in information systems** (Webster, Watson 2002) • Guidelines for the conduction of semi-structured interviews in qualitative research*** (Flick et al. 2007) **Data analysis** • Grounded Theory-inspired data analysis methods (Corbin, Strauss 2015) **Research results development** • General Guidelines of Exploratory Research by (Stebbins 2001)	*Inductive*

Notes:

*: ACM Digital Library, AISeL, EBSCOhost, Emerald Insight, IEEE Xplore Digital Library, Proquest, PubMed, and ScienceDirect
**: For literature review
***: For expert interviews

Table 5 Overview of research design of the studies included in this dissertation been identified in an *inductive* way. Moreover, study 2 employs *inductive classification* (Bailey 1994) to derive overarching conceptual categories of determinant factors for cloud adoption in healthcare organizations.

Study 3 follows guidelines by Fu et al. (2014) to systematically develop an evaluation framework that analyzes how cloud computing services support collaborative activities in healthcare services (e.g., medical diagnosis; treatment; case management). Data for study 3 was collected by using a systematic literature review and eleven semi-structured expert

Study #	Applied theory	Short description/ Relevance for the study	Role of the theory
1	Diffusion of Innovations (DoI) Theory (Rogers 2003)	The DoI Theory suggests choosing three types of knowledge to observe an innovation: 1) *awareness knowledge* (i.e., information about the existence of the innovation); 2) *how-to knowledge* (i.e., how to apply the innovation); 3) *principle knowledge* (i.e., the approach in which the innovation works)	Type 2 (*how-to knowledge*) and type 3 (*principle knowledge*) knowledge are deemed relevant for cloud computing in healthcare. They provide two basic conceptual angles for the development of a taxonomy that analyzes cloud computing services in healthcare organizations
2	Technology-Organization-Environment (TOE) Theory (DePietro et al. 1990); DoI Theory (Rogers 2003)	The TOE theory explains that the main factors that influence the decision of an organization to adopt IT are *technological*, *organizational* and *environmental* aspects. The DOI theory suggests that the characteristics of the adopted innovations (i.e., technologies) and the adopters (i.e., organizations) are crucial for the (IT) innovation adoption process	Study 2 also reviews theories that explain the cloud adoption in healthcare organizations. Relying on main concepts of the TOE theory and the DOI theory, the most applied theories according to the review, study 2 proposes a conceptual model of cloud computing adoption studies in healthcare
3	Human, Organization and Technology-fit (HOT-fit) Model (Yusof et al. 2008)	The HOT-fit Model is specifically designed to support the development of health information systems evaluation. The HOT-fit Model depicts that *human*, *organization* and *technology* factors are net benefits of a health information system. The HOT-fit Model stresses the role of relationships between every two factors, which are defined as *fit* between them. The concept of *fit* is considered as the ability of *humans*, *organizations*, and *technology* to align and integrate with each other	The concepts of the HOT-fit Model (i.e., *human*, *organization*, *technology*, and the *fits* between every two of them) provide a theoretical lens for identifying capabilities of cloud computing services that support collaborative activities in healthcare and guide the development of the related evaluation tool
4	Six-Layer Model of Colla-boration (SLMC) (De Vreede, Gert Jan et al. 2009)	The SLMC considers design concerns for general collaboration systems at six different levels of abstraction: (1) *collaboration goals*; (2) *group products*; (3) *group activities*; (4) *group procedures*; (5) *collaboration tools*; (6) *collaboration behaviors*	Six layers of the SLMC serve as the entry point of the typology of design concerns for multi-organizational multi-stakeholder collaboration systems. Categories of the typology are rooted in the six layers

Table 6 Overview of the use of theories for research design

interviews (see Table 5). For the systematic literature review, the study follows the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guidelines* (Moher et al. 2009) to review research articles coming from eight most acknowledged literature databases (see Table 5). Guided by Kvale (2007), eleven semi-structured interviews were conducted with health IT experts from China. The purpose of the literature review as well as the expert interviews is to identify data about properties of cloud computing services in healthcare organizations that support collaborative activities in healthcare. Identified data are analyzed by using *open coding* and *axial coding* technique (Corbin, Strauss 2015). Following Fu et al. (2014), the study used codes from the literature that describe the idealized or desired status of cloud computing services regarding their capabilities that support collaboration in healthcare to develop the evaluation framework. Subsequently, codes were from literature and expert interviews that represent the actual properties of cloud computing services in practice to assess the utility of the developed evaluation framework. The development of the evaluation framework is based on a *deductive* form of reasoning, whereas the assessment of the evaluation framework is based on an *inductive* form.

Guided by general guidelines of exploratory research (Stebbins 2001), study 4 explores design concerns for large-scale IT-supported collaboration in multi-organizational multi-stakeholder (MO-MS) contexts. Study 4 selects the healthcare industry as the exemplar domain for the exploration. A systematic literature review and two rounds of semi-structured expert interviews (n=50) were conducted to collect data about cloud computing services and general (in-house) IT systems regarding their capabilities that support collaborative activities in healthcare services. The collected data was analyzed by *open coding* and *axial coding* techniques (Corbin, Strauss 2015). Based on the coding results, the study derived categories of design concerns for large-scale IT-supported collaboration in the healthcare industry in an *inductive* way.

From a theoretical perspective, research design in the four studies included in this dissertation has followed or is guided by theories that have been established in IS. This is because IS senior researchers have advocated the use of theories as fundamental lens for viewing, exploring, or explaining the world (Gregor 2006). Table 6 summarizes the use of theories for the four studies included in this dissertation, highlighting how theories guide the conduction of the studies.

1.4 Overview of Studies

This dissertation consists of four studies that explore the meaningful use of cloud computing services in healthcare. The dissertation begins with a study (study 1) that investigates the basic properties of cloud computing services and their specific meanings for the healthcare industry, and suggests concrete directions for studies related to the meaningful use of cloud computing services in healthcare. As shown in Figure 1, study 2 focuses on the identification of industry-specific factors for the adoption of cloud computing services in healthcare, and studies 3 and 4 on an investigation of the way in which cloud computing services support collaborative activities in healthcare, respectively. Both focuses belong to research directions suggested by study 1. Both research directions (from a total of eleven suggested) were chosen because, on the one

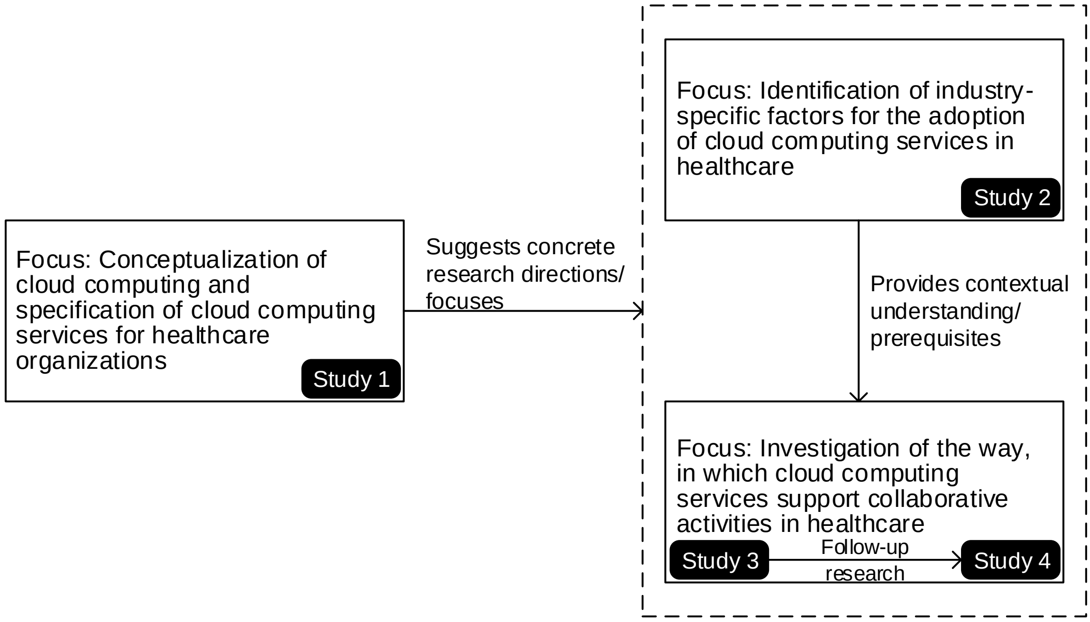

Figure 1 Relationships of the foci of the four studies included in this dissertation

hand, the identification of industry-specific factors for cloud computing adoptions assist researchers in understanding the necessary environmental contexts of the use of cloud computing services (Gao, Sunyaev 2018); it therefore serves as a necessary pre-condition to further investigate the meaningful use of cloud computing services in healthcare. On the other hand, the way that cloud computing services support collaboration in healthcare concerns a most representative area, in which the meaningful use of cloud computing in healthcare could unfold to a great extent and deserves further understanding (Gao et al. 2018b). It is stressed that, although studies 3 and 4 focus on the same research direction, study 4 is a follow-up research study that is based on the results of study 3.

Study 1 (Section 2, Gao et al. 2018b) is motivated by the research problem that concerns how previous studies about cloud computing in healthcare have relied on the interpretation of cloud computing in a common context or have been heavily based on a general understanding of traditional health IT artefacts, leading to an insufficient or unspecific conceptual understanding of cloud computing for healthcare. Based on a structured literature review and 24 semi-structured expert interviews, study 1 applies a systematic approach (see Sections 1.3 and 2) to propose a taxonomy that can serve as a fundamental mechanism for organizing knowledge about cloud computing services in healthcare organizations. The purpose of the taxonomy is to gain a deepened, specific understanding of cloud computing in healthcare.

With the taxonomy, the study focuses on conceptualizing the relevant properties of cloud computing for service delivery to healthcare organizations and highlighting their specific meanings for healthcare.

The taxonomy is composed of eight *dimensions* (i.e., different angles to observe cloud computing services) and 28 *characteristics* (i.e., values/attributes that belong to the identified dimensions) that are relevant for cloud computing services in healthcare organizations. By applying the taxonomy to classify existing cloud computing services identified from the literature and expert interviews, which also serves as a part of the taxonomy, seven specificities of cloud computing in healthcare are identified. These specificities challenge what we have learned about cloud computing in general contexts (Type 1 specificities) or in traditional health IT from the previous literature (Type 2 specificities). Table 7 summarizes the identified specificities. These specificities highlight concrete deficiencies regarding our understanding of cloud computing in healthcare contexts, based on which the study suggests eleven future research directions.

Specificity	Previous understanding	Type[a]
1. Cloud computing relies on SaaS	PaaS and IaaS in general are as relevant as SaaS	Type 1
2. Cloud computing increases data security and interoperability	Low data security and interoperability as cloud computing's downside	Type 1
3. If any, cloud computing brings only economic benefits in the long term	Reduced costs by using cloud computing in general	Type 1
4. Cloud computing focuses on clinical tasks	Health IT traditionally supports more management areas	Type 2
5. Cloud computing supports patient-centeredness	Health IT products are traditionally heavily physician-centred	Type 2
6. Cloud computing increases service mobility and flexibility	Health IT traditionally suffers from inflexible service access	Type 2
7. Cloud computing facilitates collaboration in clinical areas	Insufficient capabilities of traditional health IT to support collaboration	Type 2
Note: a Type 1: The specificity challenges what we have learned about CC in a general context Type 2: The specificity challenges what we have learned about traditional health IT		

Table 7 Overview of the identified industrial specificities of cloud computing in healthcare by study 1

Study 2 (Section 3, Gao, Sunyaev 2018) is based on the assumption that meaningful use of cloud computing services by healthcare organizations can be ensured only under certain conditions; meaning that decisions to use cloud computing services (cloud computing adoption decisions) by healthcare organizations without a serious consideration of determinant factors related to these conditions could not only hinder the meaningful use of cloud computing by healthcare organizations but also introduce difficulties. Although some studies have taken the first steps toward the investigation of cloud computing adoption specifically in the healthcare industry (e.g., Bernsmed et al. 2014; Lian et al. 2014), these first attempts rely on related research from general contexts or only address the specificities of the healthcare industry in a fragmented manner. Study 2 conducts a review of the related empirical literature from both IS and MI publication outlets to provide evidence of determinant factors that influence cloud computing adoption in healthcare.

Study 2 identifies 124 determinant factors that could influence cloud computing adoption in healthcare organizations. These determinant factors are classified into five categories that correspond to five topics that healthcare organizations should consider for cloud computing adoption decisions: (1) *technology* (i.e., characteristics of the to-be-adopted cloud computing service and the expected effects and consequences of its use); (2)

organization (i.e., the attributes and status of a healthcare organization that adopts cloud computing services); (3) *environment* (i.e., the characteristics and status of the surroundings, context or industry, in which the healthcare organization operates); (4) *data/information* (i.e., the use of data or information, or the data/information-related considerations of the healthcare organization); (5) *stakeholders* (i.e., stakeholders' characteristics, attitudes, and behaviors that are related to the adoption of the cloud computing service). After a comparison with related research in a common context, study 2 suggests that 40% (n=47) of the identified determinant factors are industry-specific. Discussion of these industry-specific determinant factors leads to two characteristics that reflect/justify their specificities for the healthcare industry: *medical and clinical role* and *public role*. The *medical and clinical role* is defined as medical/clinical specific considerations or characteristics that are related to the use of IT. Determinant factors such as *availability of medical staff* (in the healthcare organization) or *IT Vendor's medical knowledge* possess this role. The *public role* refers to certain characteristics of the healthcare industry that can be found in or are similar to the public sector to a certain extent. The *public role* describes the specificities of determinant factors such as *public-owned status* (of the healthcare organization) or healthcare organization's *intention for social gains*. Based on the identified categories of determinant factors and both roles that justify industry-specific determinant factors, study 2 proposes a conceptual model of cloud computing adoption studies in the healthcare industry. Implications of the conceptual model are discussed, based on which study 2 suggests seven concrete recommendations for future research studies regarding cloud computing adoption in healthcare.

Study 3 (Section 4, Gao et al. 2016) addresses one of the most important areas in the healthcare industry (i.e., collaboration in healthcare), in which cloud computing services can provide meaningful support (Gao et al. 2018b). Motivated by the research problem that little is known about how IT supports collaboration in healthcare, study 3 proposes an evaluation tool, highlighting six aspects of cloud computing services that facilitate collaborative activities in healthcare: (1) *user variety* (i.e., coverage of a wide range of collaborators); (2) *process perimeter* (i.e., coverage of a wide range of collaboration process); (3) *data sharing degree* (i.e., intensity of data exchange); (4) *patient involvement* (i.e., coverage of patient activities); (5) *device integration* (i.e., coverage of different devices); (6) *system interoperability* (i.e., coverage of different information systems).

Study 3 assesses the utility of the proposed evaluation tool by applying it to 38 cloud computing services in hospitals that have been identified from research (i.e., through a literature review) and from practice (i.e., through eleven expert interviews). The 38 cloud computing services are suggested by the literature and interview partners and show promising potential to support collaboration in healthcare. The evaluation results show, in general, the insufficient state of the identified cloud computing services regarding their capabilities to support collaboration in healthcare. In particular, a high proportion (61%) of cloud computing services only enable physicians as their users and thereby exclude further relevant types of collaborators; almost all cloud computing services (37 of 38) are not able to support collaboration processes across different organizations; less than one-third of the cloud computing services engage or involve participants of patients, although patients' participants are an inevitable part of collaborative activities in healthcare.

Study 4 (Section 5, Gao et al. 2018a) aims to address the design concerns of collaboration systems (i.e., information systems that support collaborative activities) in multi-organizational multi-stakeholder (MO-MS) contexts such as disaster relief, joint ventures, public administration, and healthcare. How to design collaboration systems has become a core area of Collaboration Engineering research in IS. However, current research studies have focused more on collaboration systems for general team collaboration. Design concerns of collaboration systems presented by MO-MS contexts are beyond those for team collaboration. Study 4 selects the healthcare industry as the most representative exemplar domain for exploring design concerns of collaboration systems in MO-MS contexts, because healthcare faces challenges (e.g., increasing demand of healthcare services but decreasing medical resources), and there is high potential for collaborative healthcare to mitigate those challenges.

The study conducted a two-year design science research study using the disciplines for exploratory research (Stebbins 2001) to discover and describe design concerns for MO-MS collaboration, and to formalize them into a generalizable design tool. By conducting an extensive review of literature and two rounds of, in total, 50 expert interviews, study 4 proposes a typology comprising eleven categories of design concerns and design questions related to collaboration systems in healthcare but applicable to more MO-MS contexts. In addition to general (in-house) health IT, study 4 provides a special focus on the capabilities of cloud computing services that can be used to design collaboration systems in healthcare. This is because, on the one hand, an increasing number of healthcare organizations tend to apply cloud computing to complement and improve their in-house IT (PRNewswire 2017). On the other hand, cloud computing has the potential to support collaborative activities in healthcare, as highlighted in studies 1 and 3. Thus, including cloud computing could increase the comprehensiveness of the findings.

The first category (i.e., Category 0: *collaboration practices*) of design concerns addresses concerns common to all collaboration systems. These concerns represent six basic aspects highlighted by the SLMC (see Table 6). The remaining ten categories (Category 1 to 10) elaborate Category 0 concepts with concerns that are specific to healthcare context. Category 0 therefore serves as the entry point for the rest of the categories. Category 1 (*role variety*) concerns the assortment of roles which must be involved in collaborative activities, the specific classes of events in which each role must participate, and the capabilities the system must afford to support their involvement in those events. Category 2 (*service perimeter*) concerns the variety of entities outside the organization. Category 3 (*response times*) concerns the variety of events to which the collaboration system will respond, and the capabilities the collaboration system must afford to attain the minimum necessary response time for each class of organization that should be involved in a collaboration, and the capabilities the system must afford to support their involvement. Category 4 (*device integration*) concerns the variety of data-active devices that reduces the collaborator's cognitive load (e.g., wearable sensors; smartphones; non-barrier devices) and the capabilities the system must afford to accommodate their use. Category 5 (*system interoperability*) concerns the variety of internal and external information systems with which the collaboration system must interact at the time it is deployed and in the future, and the capabilities that the system must afford to accommodate those interactions. Category 6 (*process adaptability*) concerns the variety of conditions under which people collaborate, and the capabilities the system must afford to accommodate that range of conditions. Category 7 (*user awareness*) concerns the degree to which users can know: a) with whom they are collaborating (identities and roles); b) what each person is expected to do (rules about what each role should do under what constraints using what capabilities); c) what aspect of the system each person is currently in; d) what each person is doing; e) who executed each action; f) the current states of activities; and g) the current states of the environment. Category 8 (*[patient] data integration*) concerns the variety of sources from which the most relevant data for collaboration must be gathered, the completeness of data, and the capabilities the system must afford to integrate those sources. Category 9 (*richness of system cues*) concerns the variety of media richness associated with the information cues the collaboration system provides to users (e.g., explanations, patient records, human communication), and the capabilities the system must afford to present that variety. Category 10 (*concept clarity*) concerns the variety of concepts that people must understand for successful collaboration, and the capabilities the collaboration system must afford to ensure that people gain a shared understanding of those concepts.

To demonstrate the utility of the typology, the study uses the data from the literature and the interviews to define design questions for each category that could be used to derive a more thorough exploration of requirements for that category. In total, study 4 identifies 49 design questions. Moreover, it presents how these design questions are related to six aspects of the SLMC, thereby demonstrating how Categories 1 to 10 elaborate and are rooted in Category 0.

1.5 Discussion

1.5.1 Contribution to Research

Based on the overarching research question: *How can cloud computing support healthcare organizations in a meaningful way (i.e., meaningful use)?*, this dissertation aims to improve researchers' understanding of cloud computing in healthcare contexts. As discussed in Section 1.1, the relevance of the overarching research question lies in its value for advancing IS theories. The four studies included in this dissertation could contribute to theory development in IS in diverse ways. This section demonstrates their contribution by following Gregor (2006) who suggests five types of IS theories and indicates how researchers contribute to the development of these theories.

As summarized in Table 8, these five types are used to evaluate the research findings of the four studies included in this dissertation, thereby highlighting their theoretical contributions for the IS community. According to Gregor (2006), Type I theories (i.e., *analysis*) say "what is" (p. 620) and focus on the analysis and description of IS phenomena; Type II theories (i.e., *explanation*) say "what is, how, why, when, and where", and provides explanations for but do not aim to predict with any precision for IS phenomena; Type III theories (i.e., *prediction*) say "what is and what will be" (p. 620),

Study #	Contribution to information systems theories	Theory type
1	Study 1 proposes a taxonomy of cloud computing services for healthcare organizations. The taxonomy serves as an *analysis theory* that allows researchers to analyze properties of cloud computing services for healthcare organization. Such a taxonomy is as a typical *analysis theory*, according to Gregor (2006).	Type I: *analysis theory*
2	Study 2 identifies determinant factors that could influence cloud computing adoption in healthcare. Study 2 also proposes a model that suggests the conceptual categories of the determinant factors and describes their industry-specific characteristics. The determinant factors, the conceptual categories, and the industry-specific characteristics serve as building blocks for the development of a theory that describes factors that influence cloud computing adoption in healthcare.	Type I: *analysis theory*
3	Study 3 proposes a tool that can be used to evaluate cloud computing services in healthcare regarding their capabilities to support collaborative activities. The evaluation tool contributes to the development of a theory that explains how to evaluate health information systems regarding their capabilities to support collaborative activities in healthcare.	Type V: *design and action*
4	Study 4 develops a typology of design concerns for collaborative activities in multi-organizational multi-stakeholder contexts. The typology serves as an *analysis* theory that describes the relevant aspects of collaboration systems in multi-organizational multi-stakeholder contexts. Moreover, the typology contributes to the development of a theory for designing collaboration systems that support collaborative activities in healthcare in multi-organizational multi-stakeholder contexts.	Type I: *analysis* and Type V: *design and action*

Table 8 Theoretical contributions of the four studies included in this dissertation structured by Gregor (2006)

and provide predictions for IS phenomena and have testable propositions but do not have well-developed justificatory causal explanations; Type IV theories (i.e., *explanation and prediction*) say "what is, how, why, when, where, and what will be" (p. 620) and provide predictions and have both testable propositions and causal explanations; and finally Type V theories (i.e., *design and action*) say "how to do something" (p. 620) and give explicit prescriptions (e.g., methods; principles of form and function) for constructing an artifact.

Study 1 suggests a taxonomy of cloud computing services for healthcare organizations. According to Gregor (2006), taxonomies are representative Type I theories. Type I theories for an IS phenomenon shows its value, when little is known about the IS phenomenon, as the situation of cloud computing services for healthcare organizations. The proposed taxonomy contributes to IS research by describing the characteristics of cloud computing services that are of relevance for healthcare organizations and conceptualizing cloud computing for the healthcare industry. Through the application of the taxonomy to identified cloud computing services from literature and expert interviews, the taxonomy indicates specificities of cloud computing for healthcare in contrast to common contexts and other traditional health IT artefacts.

Study 2 derives a list of determinant factors that could influence cloud computing adoption by healthcare organizations. In comparison with related research studies in common contexts, study 2 especially highlights industry-specific determinant factors. Based on the analysis of the identified determinant factors, study 2 proposes conceptual categories that describe the conceptual nature of the determinant factors. Moreover, study 2 summarizes the industrial specificities by employing two characteristics (i.e., *medical and clinical role* and *public role*). The conceptual categories and both industry-specific characteristics of the determinant factors contribute to IS research by describing industrial specificities in cloud computing adoption studies for healthcare. Although developing a theory is not within the scope of study 2, the conceptual categories and the industry-specific characteristics can serve as basic constructs of a Type II theory that analyses whether a determinant factor is relevant for cloud computing adoption in healthcare (relying on the conceptual categories) and/or whether the determinant factor is industry specific (relying on both characteristics). Because study 2 also adopts an IT innovation adoption view and an IT outsourcing adoption view for cloud computing adoption in healthcare, it is argued that the derived conceptual categories and both industry-specific characteristics can inform more general IT innovation adoption and IT outsourcing adoption studies in healthcare.

Study 3 proposes a tool that can be used to evaluate cloud computing services in healthcare regarding their capabilities to support collaborative activities. Although the proposed tool is not a Type V IS theory (i.e., *design and action*), research results of study 3 can inform the development of such a theory, namely a *design theory* (Gregor, Jones 2007). According to Gregor, Jones (2007), a *design theory* possesses six core components: (1) *purpose and scope* (i.e., the set of meta-requirements or goals that define scope or boundaries of the theory); (2) *constructs* (i.e., representations of the entities of interest in the theory); (3) *principle of form and function* (i.e., the abstract architecture that describes the theory); (4) *artifact mutability* (i.e., the changes in state of the artifact anticipated in the theory); (5) *testable propositions* (i.e., truth statements about the design theory); and (6) *justificatory knowledge* (i.e., the underlying knowledge or theory that gives a basis and explanation for the design theory). Study 3 contributes to the development of a *design theory* for evaluation tools for cloud computing services regarding their capabilities to support collaboration in healthcare in a two-fold manner. On the one hand, the six categories identified by study 3 could suggest basic *construct* for the design theory. On the other hand, the application of the proposed evaluation tool shows the *principle of form and function* of the basic *construct* (i.e., how the six categories can be used to evaluate cloud computing services), which is applicable to the *design theory*.

With a typology of design concerns for collaboration systems in MO-MS contexts, study 4 not only proposes a Type I IS theory but also contributes to the development of a Type V IS theory. The typology describes eleven categories of design concerns of collaboration systems in MO-MS contexts. The proposed design questions in each category for healthcare contexts demonstrate the usefulness of this theory for supporting researchers in their analysis and understanding of concrete collaboration challenges in a certain MO-MS context (i.e., healthcare). From a Type V IS theory perspective, the typology could contribute to developing the *construct* of a *design theory* that explains how to design collaboration systems in MO-MS contexts. Moreover, the typology has its roots in the SLMC (De Vreede, Gert Jan et al. 2009). Study 4 belongs to the first research studies that demonstrate the utility of SLMC to inform the development of collaboration systems in IS. Thereby, study 1 contributes to justifying the selection of the SLMC as *justificatory knowledge* for the *design theory*.

1.5.2 Contribution to Practice

In addition to the contribution to theory, this dissertation provides insights for health IT practitioners. The taxonomy proposed in study 1 can, for example, help cloud providers or policy makers classify available cloud computing services in a certain health IT market on a macro level to suggest new cloud computing services that address possible market gaps (e.g., PaaS for healthcare organizations, revealed by study 1). On a micro level, healthcare organizations could apply the taxonomy to understand an individual cloud computing service. By finding matches as well as mismatches between the cloud computing service's profile and their own organizational needs, healthcare organizations could screen and identify cloud computing services that would be useful to them and thereby increase the meaningful use of cloud computing. In study 2, the identified determinant factors can support cloud computing adoption projects in healthcare organizations. The determinant factors that display consistent empirical results (see Table 2 in section 3) could serve as a checklist of enablers and barriers that practitioners should not ignore for cloud computing adoption projects in healthcare. Study 3 provides a ready-to-use evaluation tool that supports healthcare organizations in evaluating cloud computing services concerning a specific topic (i.e., collaboration), while the typology in study 4 delivers concrete design questions that guide health IT practitioners in deriving concrete requirements for collaboration systems in healthcare.

1.5.3 Limitations

This dissertation is not without limitations. First, although it aims to contribute to more general healthcare contexts, it focuses on the meaningful use of cloud computing services in healthcare organizations that are hospitals and clinics. Some specific healthcare settings such as nursing homes or patient selfcare cannot necessarily be covered. This is because hospitals and clinics are not only the backbone of the healthcare industry that are involved in major healthcare activities (United Nations 2008) but also representative IT consumers in healthcare (Poon et al. 2006). It is therefore expected that research findings of this dissertation would also inform the meaningful use of cloud computing for other healthcare settings. Research that focuses on cloud computing in more specific healthcare contexts could employ the findings of this dissertation as a starting point (e.g., using *dimensions* and *characteristics* of the taxonomy in study 1 to investigate the concept of cloud computing in another specific healthcare setting).

Second, three of the four studies leverage data from semi-structured interviews. The interview partners come from China and Germany mainly because the author has access to them. The regional restrictions of the interview data certainly cannot ensure the generalizability of the research findings for common healthcare contexts because different regions and countries possess regional specificities that could influence the use of IT artefacts. To alleviate the generalizability, which is a common challenge in exploratory research, the author carefully designed the research methods by applying the following three strategies. First, structured literature reviews were conducted to complement interview data. Second, interview questions were carefully designed to also get data that are not limited to both countries. For example, study 1 asked interview partners to include cloud computing services that are not limited to their own organizations/regions. Consequently, the study also identified features of cloud computing services that are international or from other countries (e.g., Japan; the United Kingdom; the United States), which can be used for the taxonomy development. Third, different interview partners from diverse organizations were invited to ensure a broad data perspective. In study 4, for example, all 50 different interviewees came from 39 different organizations. Future research could also include data from other countries or niche cloud computing markets to further verify and improve the findings in this dissertation.

1.5.4 Impact on Future Research

This dissertation does not only deliver insights into the meaningful use of cloud computing services in healthcare but also highlights opportunities for related future research, which can also be regarded as a contribution of the dissertation. This section follows the concept of Briggs, Schwabe (2011), in order to use four modes of scientific inquiry in IS to structure the highlighted research opportunities. According to Briggs, Schwabe (2011), the value of a research study lies in its way to inform future research in one or several modes of scientific inquiries in IS: *exploratory research*; *theoretical research*; *experimental research*; and *applied science/engineering*. Figure 2 summarizes how this dissertation informs future research.

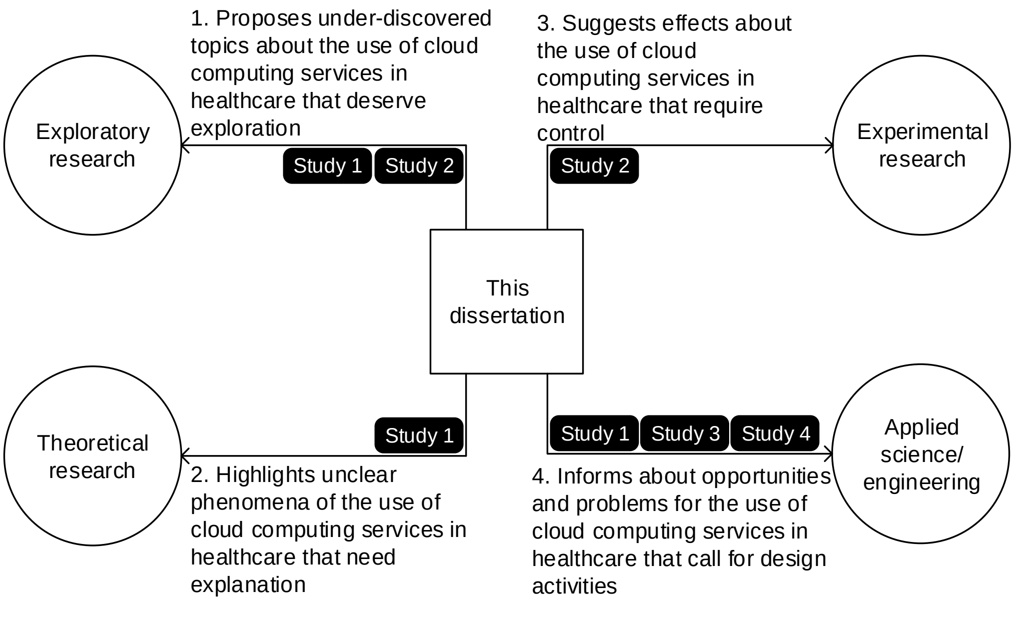

Figure 2 Impact of the dissertation on future research based on Briggs, Schwabe (2011)

For future studies in *exploratory research*, study 1 and 2 propose several under-discovered topics about the use of cloud computing services in healthcare that deserve further explorative research actions. In particular, study 1 highlights the necessity to explore how cloud adopters are aware of and/or perceive increased data security and operability for health IT through cloud computing, the ways cloud computing supports health and medical research, and how cloud computing enables patient-centeredness. Study 2 recommends that researchers explore the impact of different stakeholder groups on cloud computing adoption in healthcare, and discover further industry-specific factors that influence cloud computing adoption in healthcare that possess *medical and clinical role* and *public role*.

For *theoretical research*, study 1 highlights the unclear phenomena of the use of cloud computing services in healthcare that need explanation. These phenomena include the lack of PaaS and IaaS in healthcare, and the decreased short-term economic performance of healthcare organizations through the use of cloud computing services.

Regarding related studies in experimental research, study 2 suggests effects about the use of cloud computing services in healthcare for which experimental studies should control. On the one hand, study 2 has identified a few determinant factors that deliver consistent effects on cloud computing adoption in healthcare but have only been investigated by a limited number of empirical studies (i.e., less than five). On the other hand, some determinant factors are found to deliver conflicting empirical effects on cloud computing adoption. The effects of these determinant factors require further validation or investigation.

For future research in *applied science/engineering*, study 1 informs researchers of opportunities about the use of cloud computing services in healthcare that require design activities. For example, study 1 suggests focusing on designing cloud computing services that serve as industry PaaS or IaaS, or on designing cloud business processes to improve the economic results of the use of cloud computing in healthcare. Moreover, studies 3 and 4 reveal design issues that should be addressed by future *applied science/engineering* studies, while study 3 suggests integrating further sub-topics (e.g., economic results; data security and privacy) with the proposed evaluation tool for cloud computing services regarding the topic of collaboration in healthcare, so that a more holistic evaluation manner that also considers certain side-effects (e.g., cloud computing services that support more multi-organizational collaborative activities could face more data privacy challenges) can be ensured. Finally, study 4 recommends future research to investigate design concerns for collaboration systems in MO-MS contexts by also taking perspectives from different stakeholders into consideration. Study 4 also suggests focusing on relationships between proposed categories of design concerns, which is likely to lead to new design concerns.

1.6 Conclusion

Although the term “cloud computing” has existed since 2007, the phenomenon of cloud computing in healthcare remains in its infancy and calls for research into this phenomenon have emerged (e.g., Kuo 2011; Weigel et al. 2013; Griebel et al. 2015). Using four studies comprising this dissertation, the author takes a first step toward exploring and understanding the meaningful use of cloud computing services in healthcare organizations. Study 1 conceptualizes properties of cloud computing services for healthcare, study 2 investigates the determinant factors of cloud computing adoption in healthcare that are prerequisites for cloud computing’s meaningful use, study 3 focuses on how cloud computing supports collaborative activities in healthcare, and study 4 explores cloud computing’s properties that inform the design of collaboration systems in healthcare as well as in more general MS-MO contexts. Hence, this dissertation provides a substantial groundwork for the further understanding of the meaningful use of cloud computing services in healthcare.

2. Rethinking the Meaning of Cloud Computing for Health Care: A Taxonomic Perspective and Future Research Directions

Paper 1

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Original Paper

Rethinking the Meaning of Cloud Computing for Health Care: A Taxonomic Perspective and Future Research Directions

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Abstract

Background: Cloud computing is an innovative paradigm that provides users with on-demand access to a shared pool of configurable computing resources such as servers, storage, and applications. Researchers claim that information technology (IT) services delivered via the cloud computing paradigm (ie, cloud computing services) provide major benefits for health care. However, due to a mismatch between our conceptual understanding of cloud computing for health care and the actual phenomenon in practice, the meaningful use of it for the health care industry cannot always be ensured. Although some studies have tried to conceptualize cloud computing or interpret this phenomenon for health care settings, they have mainly relied on its interpretation in a common context or have been heavily based on a general understanding of traditional health IT artifacts, leading to an insufficient or unspecific conceptual understanding of cloud computing for health care.

Objective: We aim to generate insights into the concept of cloud computing for health IT research. We propose a taxonomy that can serve as a fundamental mechanism for organizing knowledge about cloud computing services in health care organizations to gain a deepened, specific understanding of cloud computing in health care. With the taxonomy, we focus on conceptualizing the relevant properties of cloud computing for service delivery to health care organizations and highlighting their specific meanings for health care.

Methods: We employed a 2-stage approach in developing a taxonomy of cloud computing services for health care organizations. We conducted a structured literature review and 24 semistructured expert interviews in stage 1, drawing on data from theory and practice. In stage 2, we applied a systematic approach and relied on data from stage 1 to develop and evaluate the taxonomy using 14 iterations.

Results: Our taxonomy is composed of 8 dimensions and 28 characteristics that are relevant for cloud computing services in health care organizations. By applying the taxonomy to classify existing cloud computing services identified from the literature and expert interviews, which also serves as a part of the taxonomy, we identified 7 specificities of cloud computing in health care. These specificities challenge what we have learned about cloud computing in general contexts or in traditional health IT from the previous literature. The summarized specificities suggest research opportunities and exemplary research questions for future health IT research on cloud computing.

Conclusions: By relying on perspectives from a taxonomy for cloud computing services for health care organizations, this study provides a solid conceptual cornerstone for cloud computing in health care. Moreover, the identified specificities of cloud computing and the related future research opportunities will serve as a valuable roadmap to facilitate more research into cloud computing in health care.

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KEYWORDS

cloud computing; taxonomy; health IT innovation

Introduction

Background and Objective

Cloud computing (CC) is an innovative paradigm that provides users with on-demand access to a shared pool of configurable computing resources such as servers, storage, and applications [1]. CC possesses unique features (ie, on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured services) that are argued to enhance traditional in-house health information technology (IT) approaches in health care organizations (eg, hospitals and clinics). Researchers claim that IT services delivered via the CC paradigm provide major benefits for health care, including improved flexibility in the use of IT resources [2], high availability of IT infrastructure to address ever-changing health IT demands [3], and low upfront investments and IT maintenance costs for the use of health IT [4]. Surprisingly, the benefits promised by using CC often do not hold in practice: it has, for example, been reported that the use of cloud computing services (CCSs) is tied to implementation and preparation activities that impede the flexibility of CC [5], the promised high availability of cloud-based IT infrastructures also cannot always be ensured (eg, sometimes the maximal attainable IT resources are strictly predefined) [6], and the use of CCSs is not guaranteed to yield the expected economic advantages for users in health care (eg, due to unexpected high upfront costs) [7,8]. There is therefore a mismatch between our conceptual understanding and the accepted meaning of CC for health care (ie, the value and/or consequences of using CC) in practice. Such a mismatch not only hampers the meaningful use of CC in the health care industry (ie, CC should provide constructive support) [9] but also could lead to countereffects for health care. As reported in a recent case, performance of an electronic health record system enabled by CC in a United Kingdom hospital diverged from initial expectations and led to countereffects, resulting in a £200 million (US $262 million) project failure and the hospital's inability to deliver key services on a large scale [10,11].

Although the topic of CC in health care has been widely discussed in the literature, existing publications mainly focus on development of single CC applications or platforms in health care [12-16] and development of security mechanisms for the use of CC [17-21]. Although some studies have tried to conceptualize CC or interpret this phenomenon for health care settings [4,22,23], they are heavily based on a general understanding of traditional health IT artifacts or mainly rely on the interpretation of CC in a common context, which leads to an insufficient or unspecific conceptual understanding of CC for health care. CC is an IT innovation for the health care industry that differs from traditional health IT approaches; in addition, when conceptualizing the topic of CC in health care, it is essential to seriously consider the health care context. The health care industry is markedly different from the commonly understood context and interpretation of CC [24]. Thus, this more general CC context is not necessarily adequate for health care. To this end, past research suggests that a nonspecific grasp of the CC concept in research and practice, irrespective of the intricacies of the health care sector, might be a major reason for why few successful implementations of CCSs in health care exist [25].

In this research, we rethink the meaning of CC for health care. By relying on existing CCSs in practice, we aim at generating insights into this phenomenon for health IT research. Our research focuses on the following research questions (RQs):

> RQ1: What are the relevant properties of CC for service delivery to health care?
>
> RQ2: What are the specific meanings of these properties for health care?

To address the research questions, we drew on data from a structured literature review and 24 expert interviews to develop a taxonomy of CCSs for health care organizations. Taxonomies are a form of classification [26] that are widely used to understand IT concepts in health care [27,28]. We expect to use this taxonomy to organize existing knowledge about CC in health care to fulfill our research purpose. In particular, we relied on the taxonomy to understand CC's key service delivery properties for health care organizations (RQ1) and thereby conceptualized CC for health care settings. By classifying 50 CCSs for health care organizations that we identified from both the literature and interviews using the taxonomy, we derived specificities of CC for health care (RQ2) that subverted and, therefore, challenged our understanding of CC in a common context or from a traditional health IT perspective. Our study conceptualizes CC specifically for health care. More importantly, we derived concrete research directions based on our conceptualization of CC to facilitate research on CC in health care.

Cloud Computing Knowledge in Health Care

CC is an innovation for health care organizations. In the health care industry, 3 types of innovations can be observed: (1) innovation focusing on the manner in which consumers access health care and fund the related services; (2) innovation applying technology to improve products, services, or care; and (3) innovation generating new business models [29]. CC is an innovation of applying (information) technology in health care organizations (type 2) that is in sharp contrast to traditional health IT approaches. CC provides 3 different service models—software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS)—all of which are Web-based [1]. CC can therefore deliver fundamental IT resources such as processing, storage (IaaS), and platforms together with programming languages, tools, and/or libraries that support users to develop and/or deploy software (PaaS). CC can also provide ready-to-use software applications (SaaS), which run on the cloud infrastructure, to health care organizations.

CC relies on different deployment models to provide IT services. First, in a public cloud, the infrastructure of CCSs is provided for open use by the general public. Second, the infrastructure of a private or community cloud is provisioned for the exclusive use by a single organization or a specific group of organizations, respectively. Third, a hybrid cloud is a combination of 2 or more of the aforementioned deployment models. Whereas public clouds exist off the premises of cloud users, private and community clouds may exist on or off premises.

Our research aimed at organizing knowledge about CC and conceptualizing CC in health care. We employed the concept of knowledge about innovations by Rogers [30] as a means to interpret the knowledge about CC in health care and guide the taxonomy development. We chose it because Rogers' concept of knowledge is one of the few established concepts in research that can specify an IT artifact by observing it as an innovation, which is appropriate for CC as an innovation in health care. Moreover, Rogers' knowledge about innovations serves as a basic concept in his diffusion of innovations theory. Although we did not specifically address issues regarding CC's diffusion, we aimed for a specific understanding of an innovation (in health care), which is consistent with Rogers' ultimate purpose for this concept in the diffusion of innovations theory.

According to Rogers, 3 different types of knowledge are relevant for an insightful understanding of an innovation: (1) awareness knowledge comprises information about the existence of an innovation, (2) how-to knowledge describes how the innovation can be applied, and (3) principle knowledge explains the approach in which an innovation works. In this research, we targeted how-to and principle knowledge to understand the term knowledge. This is because most are aware of the term "cloud computing" [31]. Our research focused on the properties of CCSs that describe how CC can be used in health care organizations (how-to knowledge) and the ways in which CCSs support health care organizations (principle knowledge).

Methods

Overview

We employed a 2-stage approach to develop a taxonomy of CCSs for health care organizations. As illustrated in Figure 1, we conducted a structured literature review and 24 semistructured expert interviews in stage 1, drawing on data from theory and practice. In stage 2, we employed the views of how-to and principle knowledge, applied the method used by Nickerson et al [32], and developed a taxonomy of CCSs for health care organizations. The taxonomy development method integrates the evaluation of the taxonomy into its development process such that no further a posteriori evaluation of the taxonomy was required.

Literature Review

To obtain data for the development of our taxonomy, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses framework [33] and performed a review of the literature on CC in health care organizations. We searched literature databases to identify research articles addressing the topic of CC in health care organizations. Figure 2 presents a schematic of our approach, which includes the literature databases and the search string employed. It must be emphasized that we iteratively developed our search string. We tested broader keywords (eg, "eHealth," "health IT") but decided to employ more specific keywords that target health care organizations for the final search string because our taxonomy specifically focused on health care organizations. Moreover, we found that the broader keywords did not result in many additional relevant articles but increased noise, which diminished the quality of the literature review. We performed keyword, title, and abstract searches and ultimately full-text reviews. Next, 2 researchers independently screened the identified articles. The articles were first screened using keywords, titles, and abstracts and then using the full texts. We excluded articles that were not published within the last 10 years (not up to date: the term CC was not readily used until 2007), not in English, not peer-reviewed, or did not address the topic of CC in health care organizations (off-topic). A total of 66 articles remained after the screening.

Figure 1. Research methods overview. Asterisk refers to taxonomy evaluation by means of the ending conditions. CC: cloud computing, CCS: cloud computing service.

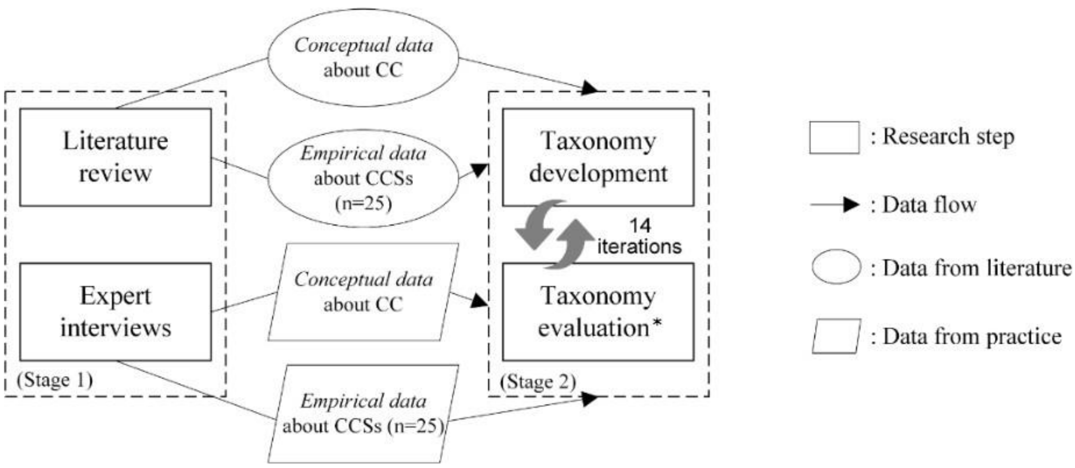
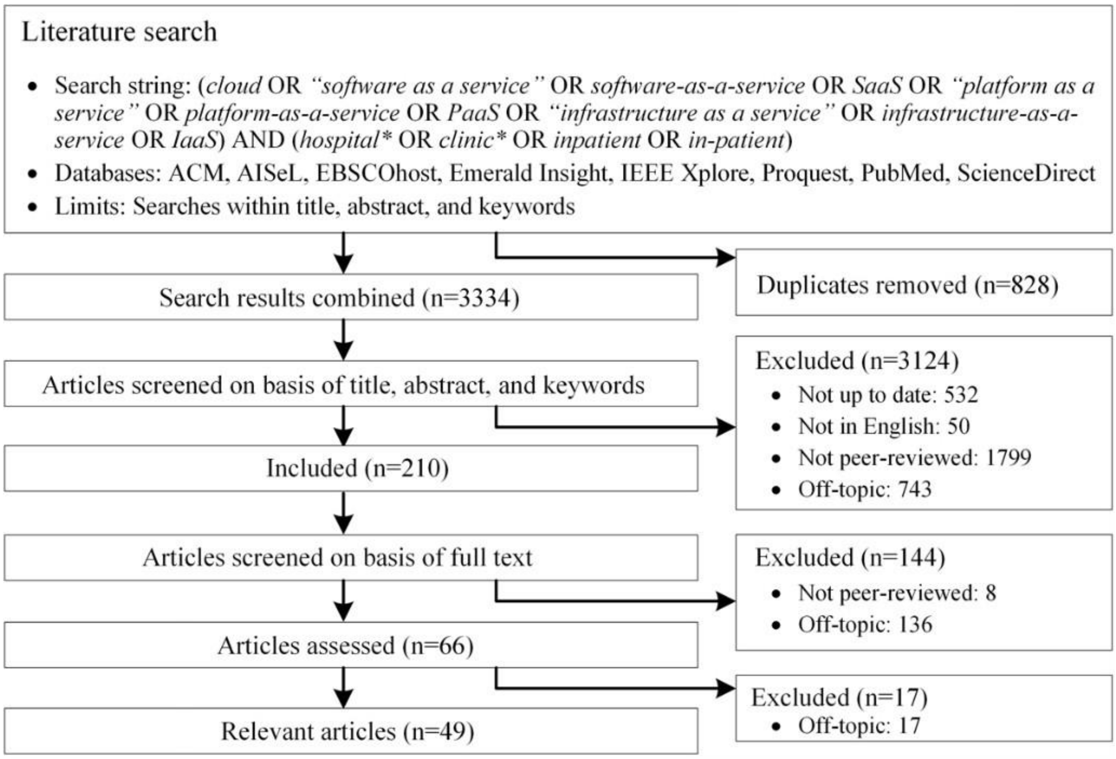


Figure 2. Flow diagram of inclusion/exclusion and literature analysis.



Once the screening was complete, we analyzed the remaining articles and identified 17 additional articles that were off-topic but could not have been excluded without an in-depth full-text assessment. This process resulted in a final sample of 49 eligible articles that were assessed in detail. With the assessment, we aimed to understand the concept of CC in health care organization contexts from a research perspective. Moreover, we attempted to identify concrete CCSs for health care organizations in addition to their characteristics from the literature. Accordingly, we classified the literature into 2 categories: conceptual and empirical. The conceptual category covered articles providing general conceptual statements about CC in health care and articles proposing CCSs that have not been deployed in practice. The empirical category contained articles describing concrete CCSs for health care organizations. This occurred because the applied taxonomy development method employed both a deductive approach (development based on data from the conceptual category) and an inductive approach (development by observing objects that need to be classified, namely, data from the empirical category) [32]. Of the 49 eligible articles, 24 were classified as conceptual and 25 as empirical. Articles that describe general features of CC and apply them to concrete CCSs were classified as special cases of the empirical category. Two researchers separately analyzed the articles. Each relevant statement was extracted and converted into 1 or more pieces of code representing a property of CCSs for health care organizations. Codes created by both researchers were compared and aggregated resulting in a master list containing codes encapsulating the properties of CCSs. The master list covers codes from both the conceptual (ie, general conceptual understanding of CC) and empirical categories (ie, concrete CCSs and their properties). It must be emphasized that 25 concrete CCSs for health care organizations were identified from the literature. A description of these CCSs can be found in Multimedia Appendix 1.

Expert Interviews

To gather knowledge that could inform the development of the taxonomy from practice, we conducted 24 semistructured expert interviews, as listed in Table 1. We applied a purposeful sampling strategy that focused on selecting individuals who are especially knowledgeable about a phenomenon of interest to recruit interviewees [34]. We included only experts who were engaged in IT activities in health care organizations and who had used, provided, or knew about concrete CCSs for health care organizations. After 24 interviews, we reached data saturation and stopped recruiting additional interviewees. The first 12 interviewees listed in Table 1 focus on the Chinese health care cloud market, and the rest focus on the German market. We selected these countries because they are the main cloud players in Asia and Western Europe, which are among the regions with the highest market share in the overall [35] and the health care cloud markets [36]. Moreover, the cloud markets in China and Germany are complementary to each other: whereas CCSs for health care organizations in Germany are restricted to European cloud providers due to data protection regulations by the European Union, CCSs in China rely on large health IT players (eg, IBM, Cisco, and Microsoft) mainly from the United States supplemented by Chinese domestic providers [37]. Thus, we were able to gain insights into knowledge about CC in health care from a wide spectrum of practices. The interviewees came from 18 different organizations and had an average of 15 years of work experience.

Table 1. Overview of interviewees.

ID	Job title	Experience in health IT[a] (years)	Work organization
i01	Chief information officer	8	General hospital in China
i02	Chief of information center	18	General hospital in China
i03	Project manager	12	International health IT provider
i04	Staff of new media department	6	Specialized hospital in China
i05	Chief of IT department	15	District clinic in China
i06	Chief executive officer	16	Chinese health IT provider for dental clinics
i07	Senior IT staff	12	General hospital in China
i08	IT supervisor	17	Chinese governmental organization for the strategic development of public hospitals
i09	Chief of information center	11	General hospital in China
i10	Senior IT staff	9	General hospital in China
i11	Vice director	12	District hospital in China
i12	Head of IT	6	General hospital in China
i13	Chief marketing officer	33	Health IT provider for the German market
i14	Staff of research and development department	30	Health IT provider for the German market
i15	Head of IT applications	20	University clinic in Germany
i16	Technology officer	10	Health IT provider for the German market
i17	Head of IT development	6	German local health IT provider
i18	Health IT developer	6	German local health IT provider
i19	Senior manager	19	German local health IT provider
i20	Head of IT	17	University clinic in Germany
i21	IT staff	10	University clinic in Germany
i22	IT team leader	19	University clinic in Germany
i23	Chief information officer	12	District hospital in Germany
i24	Head of IT infrastructure	31	University clinic in Germany

[a]IT: information technology.

Our interview guide was structured into 3 topics, as shown in Multimedia Appendix 2. Topic 1 addressed the interviewee's organization, work activities, and professional experience. Topic 2 focused on the interviewee's (conceptual) understanding of CC in health care. In topic 3, interviewees were asked to enumerate and describe all concrete CCSs in health care organizations with which they were familiar. The interviews lasted between 30 and 90 minutes, with an average of 51.33 minutes. All interviews were audio recorded and transcribed afterwards.

Two researchers separately analyzed the transcripts. For the same reasons as in the literature analysis, the interview analysis focused on not only the conceptual understanding of CC in health care but also concrete examples of CCSs, including their properties. Thus, we classified the interview data obtained from topic 2 of the interview guide in the conceptual category, whereas the interview data obtained from topic 3 fell into the empirical category. Both researchers employed the same coding technique used in the literature analysis to analyze the interview data. Consequently, we obtained a list of codes representing a conceptual view of CC in health care for the conceptual category and a list of codes representing properties of concrete CCSs in health care organizations for the empirical category. In total, 25 CCSs for health care organizations were identified from the interviews, which are presented together with the 25 CCSs identified from the literature in Multimedia Appendix 1.

Taxonomy Development

For the taxonomy development, we chose the method proposed by Nickerson et al [32], which provides a systematic taxonomy development approach for IT objects and is well acknowledged in the domain of health IT [38,39]. According to Nickerson et al [32], a taxonomy is a set of dimensions in which each dimension consists of more than 1 characteristic. In taxonomy development, several iterations are used to determine dimensions and characteristics. After each iteration, predefined ending conditions are employed to evaluate the taxonomy: if not all ending conditions can be fulfilled, the taxonomy development continues with the next iteration. In each iteration, researchers can choose between an inductive and deductive approach. A deductive approach is based on theoretical knowledge about the objects that need to be classified; an inductive approach is based on observing and analyzing a sample of the objects. For the deductive approach, we applied all data about CC from the conceptual category (see Figure 1). For the inductive approach, we employed data from the empirical category for all 50 identified CCSs in health care organizations.

Before developing a taxonomy, researchers must define a meta-characteristic and ending conditions. The meta-characteristic guides the choice of dimensions and characteristics in the taxonomy. As a result, each dimension or characteristic of the taxonomy is a logical consequence of the meta-characteristic. Our taxonomy builds on 2 relevant knowledge types of CCSs to define the meta-characteristic: how-to and principle knowledge. We defined “service delivery properties of CCSs for health care organizations” as our meta-characteristic that covers how CCSs can be used by health care organizations (how-to knowledge) and describes the approaches in which CCSs support them (principle knowledge). Both knowledge types serve as the conceptual orientation of the taxonomy as a whole. For the ending conditions, we adopted all of the objective and subjective ending conditions from Nickerson et al [32]. The subjective ending conditions also serve as criteria to evaluate the sufficiency of the taxonomy.

For each iteration, we randomly chose a developmental approach (ie, inductive or deductive). Based on the chosen approach, we randomly selected data from our data pool accordingly (ie, understanding of CC from the conceptual category for a deductive approach and concrete CCSs and their properties from the empirical category for an inductive approach). The amount of data was adjusted such that each iteration could be performed in a reasonable time frame (45 to 60 minutes).

For an iteration using the deductive approach, we first examined codes about CC to identify and summarize new characteristics and/or dimensions. We determined whether each potential new characteristic or dimension derived from a code could be considered a logical consequence of the meta-characteristic and whether there was a concrete CCS in our empirical category that could be classified into this characteristic/dimension. If both criteria were fulfilled, the new characteristic/dimension was added to the existing taxonomy. For an iteration using the inductive approach, we first examined and compared the properties of the selected CCSs from the empirical category. We attempted to derive common characteristics of the chosen CCSs by comparing their codes. If the identified characteristics were new, we attempted to assign them to existing dimensions (as characteristics) if possible. Otherwise, we grouped the characteristics, inspected their conformity with the meta-characteristic, and defined them as new dimensions for the taxonomy, if necessary. After each iteration, we applied the predefined ending conditions to evaluate our taxonomy. For an inductive approach, we additionally classified all CCSs that were analyzed using the (preliminary) taxonomy, as required by Nickerson et al [32]. After 14 iterations, we met all ending conditions and thus stopped the taxonomy development. Multimedia Appendix 3 summarizes these iterations and the data we applied to each. Because all identified CCSs for health care organizations (n=50) were analyzed in our research (ie, an objective ending condition), these CCSs were classified by the taxonomy. The final classification result serves as a part of the taxonomy.

Results

Dimensions and Characteristics

Our taxonomy of CCSs for health care organizations is composed of 8 dimensions and 28 characteristics (see Table 2 for overview). The first 4 dimensions (service form, deployment model, targeted cloud advantage, and timeliness) represent principle knowledge, which is related to the inherent mechanisms and principles of a CCS and describes the approaches in which CC supports health care organizations. The remaining 4 dimensions address concrete methods to implement (ie, how to use) CCSs for health care and represent how-to knowledge.

The service form and deployment model dimensions are consistent with the service and deployment models of CC, respectively [1]. They clarify the most basic operational principles of CCSs for health care organizations, which relate to principle knowledge. The dimension service form contains 3 characteristics: infrastructure, platform, and software, which refer to IaaS, PaaS, and SaaS of CC, respectively. The deployment model dimension indicates whether CCSs are deployed using a public, community, or private cloud. Because a hybrid cloud is, by definition, composed of 2 or more of the aforementioned deployment models, we do not define hybrid as an independent characteristic of the deployment model. Instead, our taxonomy represents a CCS with a hybrid deployment model by using 2 or more of the characteristics defined above.

The targeted cloud advantage dimension describes the concrete cloud properties from which a health care organization can benefit. This dimension highlights the effects of using CCSs and is also considered a type of principle knowledge. Scalability refers to the advantage of a CCS that extends its IT resources (eg, storage, processing, and memory) to overcome a health care organization’s IT resource scarcity or support resource-intensive tasks. Elasticity represents a CCS’s capability to dynamically allocate available resources based on users’ demands and thus optimize resource use for all users. Ubiquity indicates that users can access the CCS from any location. Cost efficiency emphasizes the cost advantage brought by CCSs. Shareability refers to the ability of CCSs to enable the efficient exchange and sharing of data between different users, whereas interoperability denotes the ability of a CCS to smoothly integrate and operate with disparate systems and machines. Security allows health care organizations to take advantage of cloud providers’ advanced data security mechanisms or technologies.

Timeliness assesses how quickly CC is able to deliver services and related data to health care organizations (real time vs not real time) and thus relates to principle knowledge. We define a CCS as real time if it is ready to process or transfer data at any time, such that the computational results and requested data are immediately available.

Table 2. Taxonomy of cloud computing services for health care organizations.

Dimension	Characteristics
Principle knowledge	
Service form	Software, platform, infrastructure
Deployment model	Public, private, community
Targeted cloud advantage	Scalability, elasticity, ubiquity, cost efficiency, shareability, interoperability, security
Timeliness	Real time, not real time
How-to knowledge	
Supported task	Clinical, administrative, strategy, research
User	Patient, medical staff, family member
Service delivery device	Independent, adapted, specialized
Patient data involvement	Internal, external, no involvement

The supported task dimension specifies the areas in which health care organizations use CCSs. This dimension highlights the manner in which CC supports health care and is deemed a type of how-to knowledge. Supported task includes 4 characteristics: clinical, administrative, strategic, and research. Clinical refers to medical activities in health care organizations that are directly associated with patient diagnosis and treatment. Administrative denotes management or support tasks in health care organizations, such as patient registration, admission, and discharge. Strategic represents tasks performed by management teams in health care organizations, such as strategic planning decisions, human resources management, and performance evaluations. Research represents all activities that are related to medical research.

The user dimension relates to how-to knowledge and aggregates the possible user types of CCSs. This dimension differentiates between a patient who receives medical treatment at a health care organization, the medical staff (health care professionals as well as administrators), and the family members of the patient.

Service delivery device refers to how-to knowledge because this dimension represents the types of client devices used to access the CCS. A CCS with an independent characteristic allows users to access services using any computer or mobile device. Adapted specifies that a CCS is compatible with different types of devices but operates more efficiently on a certain group of devices (eg, mobile phones or tablets) via technical adaptation to those devices (eg, developing specialized applications for tablets or compressing data to accelerate data transfer for mobile phones). Specialized represents those CCSs that can be accessed by only 1 or several designated groups of devices, such as authorized tablet computers, workstations in health care organizations, or specific medical devices.

Finally, the patient data involvement dimension, which also relates to how-to knowledge, explains how patient-related data are used to deliver services. Internal indicates that a CCS uses patient data that are internally available to the health care organization for IT service delivery. External refers to a situation in which a CCS uses patient data collected from external sources, such as outside medical professionals or the patients themselves. No involvement indicates that a CCS does not have access to patient data and thus does not use such data in IT service delivery.

Classification and Evaluation

After completing all taxonomy development iterations, we classified all 50 CCSs that we identified during stage 1. Multimedia Appendix 4 presents the final classification results. In this section, we provide an example of how our taxonomy can be used to classify CCSs for health care organizations. This example examines a hospital decision support system for bed-patient assignments (see C22, Multimedia Appendix 1). Because this CCS addresses patient administration and assists hospital leadership in measuring and benchmarking hospital operations, it supports both administrative and strategic tasks. The CCS is delivered in the form of a software application and is hosted in a public cloud environment. The targeted cloud advantage is scalability because the hospital benefits from CC's computing resources to analyze large quantities of data based on complex mathematical models. The CCS does not operate in real time (not real time). It is used by medical staff and is not device-specific (independent). Finally, the patient data processed by the CCS are internal.

Our taxonomy fulfills all predefined ending conditions after 14 development iterations. In particular, the fulfillment of 5 subjective ending conditions indicates high sufficiency of the taxonomy. We summarized these subjective ending conditions and provide a justification for the fulfillment of each condition in Multimedia Appendix 5. Notably, the subjective ending conditions describe the essential features of the derived taxonomy.

Discussion

Principal Findings

Specific Meanings of Cloud Computing for Health Care and Research Opportunities

By observing the taxonomy, which includes the classification results of CCSs for health care organizations, we obtained specific implications of CCSs for health care.

Table 3. Specificities of cloud computing for health care.

Number	Specificity	Previous understanding	Type
1	CC[a] relies on SaaS[b]	PaaS[c] and IaaS[d] in general are as relevant as SaaS	Type 1[e]
2	CC increases data security and interoperability	Low data security and interoperability as CC's downside	Type 1
3	If any, CC only brings economic benefits in the long term	Reduced costs by using CC in general	Type 1
4	CC focuses on clinical tasks	Health IT[f] traditionally supports more management areas	Type 2[g]
5	CC supports patient-centeredness	Health IT products are traditionally heavily physician-centered	Type 2
6	CC increases service mobility and flexibility	Health IT traditionally suffers from inflexible service access	Type 2
7	CC facilitates collaboration in clinical areas	Insufficient capabilities of traditional health IT to support collaboration	Type 2

[a]CC: cloud computing. [b]SaaS:
software as a service. [c]PaaS:
platofrm as a service.
[d]IaaS: infrastructure as a service.
[e]The specificity challenges what we have learned about CC in a general context.
[f]IT: information technology.
[g]The specificity challenges what we have learned about traditional health IT.

As demonstrated in Table 3, these implications offer 2 types of challenges to our previous understanding of CC in health care: they challenge what we have learned about CC in a general context (type 1) and in published traditional health IT studies (type 2). We employed the term "specificities" to summarize these implications, thereby highlighting the specific meanings of CC for health care. More importantly, as shown in Figure 3, the summarized specificities suggest research opportunities with exemplary research questions, facilitating future research about this relevant phenomenon in health IT.

Specificity 1: Cloud Computing in Health Care Relies on Software as a Service

Previous studies show that in a common context, PaaS and IaaS are as relevant as SaaS in the cloud market [40]; however, this result is challenged by CC in the context of health care (type 1). We found that 92% (46/50) of the CSSs deliver services in the form of SaaS (dimension service form). The identified research articles and the interviewees even applied the term "X as a service," such as "hospital information system as a service" [41] or "documentation as a service" (i17), to emphasize the importance of such CCSs, although by their nature they belong to SaaS. This is possibly because health care organizations expect to exploit the advantages of SaaS to the greatest extent and in a timely manner.

For hospitals, cloud almost only means software as a service because many hospitals want to use (them as) off-the-shelf products. ...SaaS products that support medical areas are especially welcome because hospitals always expect to get immediate improvement from the cloud in their core business. [Interviewee i03]

The lack of PaaS and IaaS in health care organizations indicates an insufficient state of CC in health care, which was confirmed by several interviewees (i07-i08, i10, i17-i19). For PaaS, our taxonomy shows only one CCS (C06), although several interviewees noted the urgent need for industry-specific PaaS.

We want to develop our own SaaS, but there is just no specific PaaS for health care organizations. General PaaS are not enough. [Interviewee i07]

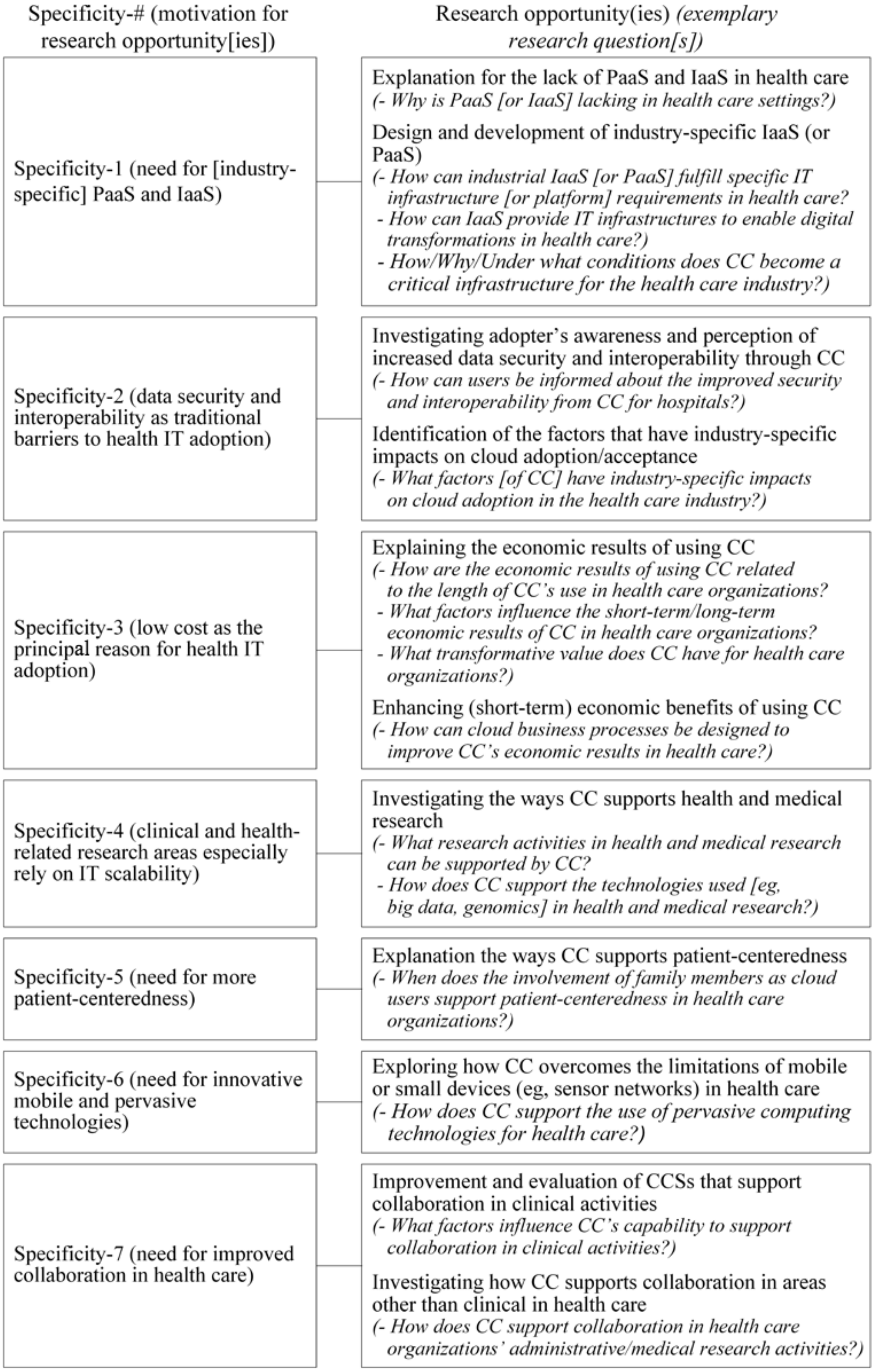
The need for PaaS in health care is not only because PaaS in general provides ready-to-use technical support for programmers but also because it has the potential to provide solutions to effectively fulfill industry-specific IT requirements. This is, for example, explained by an interviewee who was involved in developing a CCS for a hospital.

There were so many complex things we had to consider for hospitals. We kept wasting time on unnecessary meetings to find technical solutions. I dreamt of having a PaaS that could support us. ...Of course, there is more. ...Compliance is also a main topic. Hospitals ask over and over again whether our software is compliant with this or that. ...Example HIPAA: If the PaaS we use is compliant with HIPAA, then we can tell them: Yes, our software is HIPAA-compliant. [Interviewee i17]

Further industry-specific IT requirements that can potentially be supported by a health care PaaS—constant demand on cutting-edge technologies, high health IT agility (to meet changing medical requirements), the need for different domain-specific medical data structures, and support for industrial joint implementation activities (eg, between government and hospital)—were also mentioned by the interviewees.

For IaaS, previous research studies [42] and our interviewees both emphasized the strategic meaning (i08) of IT infrastructure (ie, critical information infrastructure) for the health care industry and consequently the extremely high importance of IaaS (i20) for health care organizations. We identified only a limited number of IaaS (n=3) used for general administration of health care organizations (C28, C37) or data storage (C38), which hardly fulfills all health care organization IT infrastructure requirements.

Figure 3. Research opportunities for cloud computing in health care. CC: cloud computing, CCS: cloud computing service, IaaS: infrastructure as a service, IT: information technology, PaaS: platform as a service.



Future research could focus on exploring the lack of PaaS and IaaS for health care. As revealed by our interview data, there is a particular need for research studies that systematically investigate specific requirements for health care that cannot be covered by PaaS and IaaS in a common context and thus a need to design and develop industry-specific PaaS and IaaS.

Specificity 2: Cloud Computing Brings More Data Security and Interoperability to Health Care

Previous studies have raised concerns about security and privacy as the Achilles heel of CC [43], which are main barriers for the adoption of health IT artifacts [44,45]. These concerns might be more severe for public clouds, whose infrastructures are accessible by many different users [46]. However, the dimension deployment model indicates that more than half of the investigated CCSs are based on public clouds, especially given that almost all of these CCSs involved patient data (dimension: patient data involvement) that were sensitive and entailed security or privacy issues. To this end, providing a high level of data security was regarded as a targeted cloud advantage in 10 of the identified CCSs, of which 6 were deployed on public clouds. This challenges our understanding of CC in a general context (type 1). Additionally, interoperability may also impede the adoption of CC in a general context [47]. For health care, however, our taxonomy demonstrates that increased interoperability is a benefit of CC. Security and interoperability are traditionally the most intractable challenges in health IT, and industry standards concerning IT security and interoperability in health care are evolving [9]. Cloud providers can devote resources to the implementation of industry standards or best practices that many hospitals cannot afford [4]. CC can thereby address security and interoperability issues in a more effective manner, which was confirmed by the interviewed experts (i03-i04, i06-i07, i10, i13-i14, i16-i18, i21).

CC is safe. The problem is how to make people believe that. [Interviewee i13]

Data security, interoperability...these are pluses. Speaking of data security, using paper is also not safe, if you insist on saying a cloud is not safe. [Interviewee i21]

As highlighted in Figure 3, future research could investigate the role of security and interoperability in cloud adoption studies and focus on the adopter's awareness or perception of increased data security and interoperability from CC in health care settings. Moreover, researchers could focus on exploring the factors (such as security and interoperability) that have industry-specific impacts on cloud adoption in health care, in contrast to a general context.

Specificity 3: Cloud Computing Brings Economic Benefits to Health Care Organizations, if Any, Only in the Long Term

It is surprising that CC offered economic advantages (cost efficiency) for only 11 of the 50 CCSs. In a general context, the use of CC is heavily motivated by short-term economic interests [48]. Research relying on this general understanding of CC claimed the low costs were the principle advantage of CC in health care [4]. Our research challenges the understanding of CC in a general context (type 1) by revealing that when using CCSs, many health care organizations frequently must transfer large volumes of data to and from the cloud (eg, medical images [49]). This can cause data transfer bottlenecks due to the obsolete (network) infrastructures currently in place at many health care organizations—a typical industry-specific IT issue (i02, i08, i15). Thus, CC might still require significant short-term investments in health care organizations' network resources, internet bandwidth, or other relevant infrastructures. It is therefore not surprising that the interviewees were not convinced of the potential financial advantages of using CC in health care (i01-i05, i07, i10, i17). They (i01-i02, i10) even noted that additional expenses for CC, such as consulting fees, could increase health care organizations' expenses. However, our interviewees reported that in the long term, CC will reduce their general IT maintenance work (i02, i24) and help them avoid possible IT reinvestments (i22). Future research could therefore focus on (re)examining and explaining the economic results of using CCSs in health care organizations. Moreover, researchers could focus on CC business processes or investment strategies in health care settings that enhance the short-term benefits for health care organizations.

Specificity 4: Cloud Computing Mainly Focuses on Clinical Tasks (by Leveraging High Scalability)

We recognize that most of the identified CCSs (36 of 50) support clinical tasks in health care organizations (dimension: supported task). This observation challenges previous studies about traditional health IT (type 2), which have concluded that health care organizations primarily focus on the use of IT applications for administrative, strategic, or financial functions rather than clinical activities [50]. These findings reflect an urgent need to use CC to remedy the deficiencies of traditional health IT in the context of health care organizations' clinical activities, as revealed by our literature review [51].

In clinical practice, even ordinary data analysis occasionally overwhelms traditional health IT with large volumes of data and complex analytical algorithms. [Interviewee i16]

CC can address this problem with highly scalable IT resources and is therefore considered a "powerful weapon for IT tasks in the clinical area" (Interviewee i03).

This viewpoint is supported by our taxonomy, as more than 70% (23/32) of the CCSs possessed high scalability as one of their advantages (dimension: targeted cloud advantage), with a focus on clinical areas. For research opportunities, we suggest researchers concentrate on CC that supports research tasks in health care because both the literature [52] and our interviewees (eg, i18) reveal that research activities in health care depend even more on highly scalable IT resources to address large amounts of data, which is currently managed only in a small number of identified CCSs (n=6).

Specificity 5: Cloud Computing Supports Patient-Centeredness

A conservative but still well-recognized view of health IT is that medical staff are the main users of health IT applications [53,54], and many existing health IT applications are heavily physician-centered. However, the evidence from our taxonomy challenges this view (type 2) and implies a high potential of CC to realize patient-centeredness—a promising future direction for health IT [55]. Regarding the user dimension, we noticed that 8 identified CCSs included patients as their users, which is a premise of patient-centered health IT services. Among them, 7 CCSs were patient-centered (C05, C07, C10, C26, C29, C32, C34), as they possessed 3 essential attributes of patient-centered health IT: patient-focused, patient-active, and patient-empowered [56]. Additionally, several interviewees (i02, i07-i08, i11) noted that CC innovatively involves patient family members to realize patient-centeredness, as did 2 identified CCSs (C26, C29). An interviewee, whose hospital deploys a medical appointment CCS for patients, had this to say:

Seniors, the disabled, or someone who doesn't like technologies also needs to use appointment services, so we decided to involve their relatives. ...Although we have to have more users and processes now, I believe CC can offer the necessary computer resources. It's a good thing, and I think this might be a reason to have more CCSs. [Interviewee i02]

We even have some patients who don't use the Internet at all. Their children could help them...only in this way can we ensure that each patient truly benefits from our services. [Interviewee i08]

Despite the potential of CC to support patient-centeredness, only a limited number of patient-centered CCSs were identified in this study. Future research could therefore focus on examining how CC supports patient-centeredness and on designing further CCSs that support it.

Specificity 6: Cloud Computing Increases Service Mobility and Flexibility

We found that 42% (21/50) of the identified CCSs adapt themselves to or are specialized for certain devices for service delivery (dimension: service delivery device). For CCSs that support clinical tasks, this rate is even higher (16/36, 45%). In general, a barrier impeding the use of health IT is the alteration of users' traditional workflow paradigm [57]. For health IT that supports clinical functions, physicians who are forced to adapt health care delivery processes to technologies are often unwilling to use it. Our taxonomy reveals that almost 80% (16/21) of the CCSs that were adapted to user devices, such as mobile phones and tablet PCs or other specialized medical devices, targeted service ubiquity (dimension: targeted cloud advantage) and thus the mobility and flexibility of IT service delivery (type 2). Existing health IT research concluded that these devices are inherently subjected to limited computing capacity and are criticized as unsuitable for complex tasks, such as clinical work [58]. However, our research shows that more than one-third (8/21) of the CCSs that were adapted to user devices enjoyed the benefit of resource scalability (dimension: targeted cloud advantage). Thus, as emphasized by our interviewees, CC can effectively "offset the [traditional] limitations of mobile devices or other small devices. It can increase the use of innovative devices in health care" (Interviewee i07). Future research could explore how CC overcomes the limitations of mobile or small devices in health care, which is a relevant but underinvestigated topic in health IT [58].

Specificity 7: Cloud Computing Facilitates Collaboration in Clinical Settings.

Our taxonomy demonstrates that most of the CCSs (46/50) involved the use of patient data (dimension: patient data involvement). One major expected purpose of involving patient data in health IT is to employ the data as a means to link users or systems in different clinical areas and thereby facilitate their collaboration [59]. However, research generally highlights a lack of sufficient health IT applications that support collaboration [60]. Our taxonomy challenges this (type 2) and reveals that CC has the potential to address this issue, as 21 of the 46 CCSs (that involve patient data and support clinical areas) possessed shareability or interoperability as an advantage (dimension: targeted cloud advantage) and had improved collaboration between users or systems as one of their main purposes. However, these CCSs are not without limitations. Only a small fraction of these CCSs (6/21) involved patient data from external sources (dimension: patient data involved). Including patient data from different sources is the basis of collaboration in clinical activities [51]. Our interviewees (i02, i05, i08, i11, i15) noted that including patient data from external sources (eg, external medical professionals or patients themselves) is relevant for improving collaboration in clinical processes because "no hospitals can depend only on themselves. They need continual cooperation with, at least, patients" (Interviewee i02).

The interviewees remarked that CCSs in health care organizations that have a collaboration purpose mostly focus on internal data exchanges (which was also revealed by our taxonomy), although they believed that CC has the potential to also facilitate collaboration with external parties. The timeliness dimension is another indicator for collaboration because it addresses how intensively data exchanges occur. However, for the 21 CCSs that supported clinical areas and possessed the shareability or interoperability characteristics, we found that only 8 enabled real-time data exchanges. Real time is crucial for effective data exchanges and the resulting collaboration in clinical processes (i05-i06, i08, i11, i18).

Collaboration [based on data exchanges] should not only take place but also in a real-time manner. A delay of important data for even a few minutes could be fatal for clinical activities. [Interviewee i08]

Future research should therefore strive to improve CCSs for collaboration in clinical activities due to the currently (still) insufficient state of CCSs (as well as general health IT [51,60]) for supporting collaboration. Moreover, researchers could also investigate how CC supports collaboration in areas other than clinical settings in health care.

Contributions

For health IT research, our contributions are threefold. First, we suggest a taxonomy that structures the knowledge of CCSs (ie, CCS properties) for health care organizations. In particular, our taxonomy targets principle and how-to knowledge to systematically conceptualize the concept of CC for health care settings. Unlike previous research that heavily relied on CC literature from common contexts or on traditional understandings of health IT, our study analyzed CC's industry-specific properties not only from the health IT literature but also from practice. Thus, the derived dimensions and characteristics of the taxonomy highlight the aspects of CC that are most relevant to health care. We thereby contribute to closing the gap between an insufficient conceptual understanding of CC and the actual phenomenon in practice for health care. Second, our taxonomy suggests 7 specificities that subvert and thus challenge our previous understanding of CC in a general context or of traditional health IT. These specificities advance the understanding of CC in health care. Third, we derived concrete research opportunities for health IT (see Multimedia Appendix 6 for a summary). As presented at the beginning, health IT researchers have been interested in the development of single CC applications or data security topics. For both topics, we provide suggestions that guide future research (eg, to focus on developing CCSs that enable collaboration in health care) or even create new opportunities and directions (eg, to focus on inherently increased, instead of decreased, IT security in health care by using CC). In addition, we noticed that research topics on CC are by nature broad and diverse, which should not be limited to the development of CC applications and IT security, as in current health care settings, but can include more areas such as its business perspective [61,62], its adoption (by organizations) [63,64], user awareness and acceptance [65,66], and its certification [67-69]. The proposed research directions in this study are a step toward facilitating research on CC in health care settings.

For health IT practice, the derived taxonomy can be applied to investigate CCSs for health care organizations on 2 different levels. On a macro level, the classification of available CCSs in a certain health IT market using the taxonomy can serve as an indicator of the current state of these CCSs. Cloud providers or policy makers could, for example, suggest new CCSs that address possible market gaps (eg, PaaS for hospitals). On a micro level, health care organizations could apply the taxonomy to understand an individual CCS. In particular, by combining the characteristics from the dimensions that a CCS possesses, health care organizations could specify each CCS's profile as demonstrated, for example, by the hospital decision support system for bed-patient assignments, as referred to in the Results section. By finding matches as well as mismatches between the CCS's profile and their own organizational needs, health care organizations could screen and identify CCSs that would be useful to them and thereby increase the meaningful use of CC.

Limitations and Conclusions

A main limitation of this research is that our data focused on health care organizations that are hospitals and clinics, as implied by the literature review search string and by the interview questions. This is because hospitals and clinics are not only the backbone of the health care industry [70] but also representative IT consumers in health care [71]. We therefore expected that a taxonomy derived from hospitals and clinics would provide more generally valid insights into CC for health care settings. Research that focuses on CC in more specific health care settings (eg, nursing homes) could employ our taxonomy as a starting point. We suggest that such research use the proposed dimensions and characteristics as a checklist to investigate CC. If required, adjustments along the taxonomy's dimensions and/or characteristics can be easily carried out [32], resulting in more specific taxonomies that are useful for certain health care settings. Future research should also broaden the perspective on the topic of CC to cover further health care settings by using, for example, more general search strings for literature reviews (eg, including terms such as "health IT" and "eHealth") or by designing interview topics that cover CCSs in other health care areas.

Our work relied on data from 24 expert interviews, which does not necessarily guarantee that all CCSs for health care organizations from practice were discovered. However, the selection of our interviewees ensured a wide spectrum of knowledge about CC in health care in Asia, Western Europe, and the United States, which represent the main CC health care markets. Future research could also include niche CC markets to further verify and improve our taxonomy.

Although the term "cloud computing" has existed since 2007, the phenomenon of CC in health care remains in its infancy and calls for research on this phenomenon have emerged [4,25]. By relying on perspectives from a taxonomy for CCSs for health care organizations, we provide a solid conceptual cornerstone for research about CC in health care; moreover, the suggested specificities of CC for health care and the related future research opportunities will serve as a valuable roadmap.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Overview of identified cloud computing services.

[PDF File (Adobe PDF File), 468KB - jmir_v20i7e10041_app1.pdf]

Multimedia Appendix 2

Overview of interview questions.

[PDF File (Adobe PDF File), 415KB - jmir_v20i7e10041_app2.pdf]

Multimedia Appendix 3

Taxonomy development iterations.

[PDF File (Adobe PDF File), 31KB - jmir_v20i7e10041_app3.pdf]

Multimedia Appendix 4

Taxonomy of cloud computing services for health care organizations.

[PDF File (Adobe PDF File), 595KB - jmir_v20i7e10041_app4.pdf]

Multimedia Appendix 5

Taxonomy's fulfillment of the subjective ending conditions.

[PDF File (Adobe PDF File), 427KB - jmir_v20i7e10041_app5.pdf]

Multimedia Appendix 6

Future research directions.

[PDF File (Adobe PDF File), 480KB - jmir_v20i7e10041_app6.pdf]

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Abbreviations

CC: cloud computing
CCS: cloud computing service
IaaS: infrastructure as a service
IT: information technology
PaaS: platform as a service
RQ: research question
SaaS: software as a service

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Multimedia Appendix 1: Overview of Identified Cloud Computing Services

ID	Short description [source(s)][a]
C01	C01 is a cloud-based clinical decision support system that is used for early recognition of a certain disease by means of analysis of the patient [1]
C02	C02 is a cloud computing service (CCS) that is used for the recognition of and treatment for an infant disease. Based on analyses of patient data, C02 supports treatment scheduling and coordinates treatment processes across different units within a hospital [2]
C03	By storing, managing and exchanging a data index in the cloud, C03 enables users to search for and share patient data stored in different information systems from different hospitals [3]
C04	C04 is a cloud-based electronic health record (EHR) system that supports a hospital in collecting health-related information by using mobile devices in rural areas [4]
C05	C05 is an outpatient monitoring system for pregnant women [5]
C06	C06 is cloud-based platform that supports the development and deployment of health-related IT services in a hospital. In particular, C06 can be used to secure, capture, store and consume sensitive health care data [6]
C07	C07 is a cloud-based EHR system that supports the management, storage, access, and sharing of patient data within a hospital [7]
C08	C08 is a real-time remote consultation system for emergency medical services based on patients' electrocardiography. C08 is used to process, visualize and share patient data and support decision making [8]
C09	C09 is used to support a complex treatment process within a hospital. The system monitors and guides different stages of the process [9]
C10	C10 is a patient monitoring system for chronic disease treatment. It monitors patients' vital signs and enables remote medical consultation [10]
C11	C11 is a picture archiving and communication system that is used to store and process medical images in a hospital [11]
C12	C12 is a cloud-based EHR system owned by a large-sized city hospital that supports outside clinics and doctors in rural areas [12]
C13	C13 is a cloud-based EHR system that supports offsite remote access of internal patient data using mobile devices [13]
C14	C14 is a cloud-based system for processing and storing medical data in a hospital [14]
C15	Based on analyses of patient data, C15 is a remote patient monitoring system for critical care [15]
C16	C16 is a monitoring system for patients in cardiac rehabilitation [16]
C17	C17 is a cloud-based picture archiving and communication system for sharing medical images between different users and terminals [17]
C18	C18 is a service for accessing and sharing patient data across different hospitals for disaster response [18]
C19	C19 is a service owned by a hospital that allows outside medical professionals to order laboratory tests and access test results [19]

Multimedia Appendix 1: Continued

ID	Short description [source(s)][a]
C20	C20 is an ERP system that supports emergency medical services by providing integrated patient data [20]
C21	C21 is a cloud system for the transmission of the results of electrocardiograms [21]
C22	C22 is a hospital decision support system that employs complex mathematical models to periodically recommend bed-patient assignments [22]
C23	C23 is a virtual desktop service that is shared by a group of hospitals [23]
C24	C24 is a virtual desktop solution for all areas in a hospital [24]
C25	C25 supports clinical decisions for a complex disease based on analyses of patient data [25]
C26	C26 is an IT service that enables patients and their relatives to book and manage medical appointments at a hospital. C26 also allows patients to view laboratory reports related to their appointments and upload their own image files (eg, medical image data from other hospitals) to support diagnoses [i01, i07]
C27	C27 is a CCS provided for physicians in a hospital that allows them to view and share patient information with each other using authorized mobile devices [i01]
C28	C28 is an IT service that provides IT infrastructure for IT platforms and IT applications for a hospital's administrative departments [i02, i12]
C29	C29 is a medical appointment management tool that enables patients to book medical appointments in a hospital. C29 also allows patients to view laboratory reports related to their medical appointments [i02, i04, i10]
C30	C30 is an IT service for physicians in a general hospital that enables its users to directly view and share medical images on authorized tablet computers [i03]
C31	C31 is a web service that is used to support radiology information systems and provides enterprise-wide image processing (eg, 3D/4D visualization) across clinical care areas in a hospital [i03]
C32	C32 is a web-based CCS that enables patients to book medical appointments for certain top-rated hospitals in Shanghai [i04, i08]
C33	C33 is a cloud-based platform provided for a group of small-sized hospitals in a district of a Chinese city. C08 enables the processing and sharing of patients' electronic medical records and thus facilitates collaboration within these hospitals [i05]
C34	C34 is a web application that provides remote real-time medical consultation services for patients. C34 enables real-time voice and video communications between physicians and patients. C09 employs sensors and other specialized medical devices to collect patients' vital signs, such as blood pressure and heart rate [i05, i11]

Multimedia Appendix 1: Continued

ID	Short description [source(s)][a]
C35	C35 is an internet-based cloud solution for hospital information systems in dental hospitals that integrates all standard applications and information systems for a common dental hospital [i06]
C36	C36 is a cloud-based virtual desktop solution deployed in a general hospital. C11 covers all applications available in the hospital [i08, i09, i22]
C37	C37 is a cloud service that provides IT infrastructure for whole hospital areas [i12]
C38	C38 is a cloud-based service that provides IT storage infrastructure for medical image archiving systems in hospitals. [i13, i14, i16]
C39	C39 is a cloud service used by hospitals to assess their key performance [i13, i14]
C40	C40 is a cloud service for a community of hospitals used to share medical image data, exchange opinions on medical images, and transfer patient data [i15]
C41	C41 is a browser-based system used to document and monitor oncological clinical studies in hospitals [i17, i19]
C42	C42 is a decision support system for sample selection and patient recruitment for oncological clinical studies in hospitals [i17, i19]
C43	C43 is a web-based solution that can be used to centrally store and process medical image data for a hospital. C43 also provides e-learning based on its image data [i18]
C44	C44 is a web-based IT service that enables data-sharing for research or administration purposes between different partner hospitals [i20, i22, i23]
C45	C45 is a data storage service for long-term archiving of clinical image data in hospitals [i20, i24]
C46	C46 is web-based service used to view, search and share clinical reference information for medical research [i21]
C47	C47 is a web-based IT solution for employee recruitment and staff training management in a hospital [i22]
C48	C48 is a cloud service used for food selection and purchase in a hospital [i23]
C49	C49 is an IT service used to manage all construction projects in a hospital. Users can view the status and technical details of all on-going projects and communicate with building contractors [i23]
C50	C50 is a cloud-based solution that supports a hospital's daily office business, such as word and table processing, email functions, and schedule management [i24]

Note:

a. For data sources from expert interviews (labelled with [i#]) cf. Table 1 in the paper)

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Multimedia Appendix 2: Overview of Interview Questions

#	Question	Purpose
1	Where do you work? Please describe your working position and your scope of duties or your working activities in your organization.	To identify interviewee's scope of duties and thus validate her eligibility for the interview
2	How many years of work experience do you have in your line of work?	To determine interviewee's professional experience
3	How many employees do you have in your organization?	To obtain information about the organization size
4	What do you understand about cloud computing in health care organizations?	To verify expert's qualifications and obtain data about the concept of cloud computing in health care organizations
5	What do cloud computing mean to health care organizations?	To verify expert's qualifications and obtain data about the concept of cloud computing in health care organizations
6	Is your hospital/clinic currently using any cloud computing services? Is your organization providing any cloud services for hospitals/clinics? What are these cloud services?	To address concrete cloud services for health care organizations, in which the interviewee is involved
7	Do you know of any other cloud computing services being used by hospitals or clinics that you are familiar with? What are these cloud computing services?	To address further cloud services for health care organizations that the interviewee is familiar with
8	For each of the cloud computing services you mentioned, what concrete services does it provide?	To identify the purpose of each concrete cloud computing service
9	For each of the cloud computing services you mentioned, please describe how it works and supports hospitals.	To address the basic functions of each concrete cloud computing service
10	For each of the cloud computing services you mentioned, what concrete features or characteristics does it possess?	To address the features of each concrete cloud computing service
11	For each of the cloud computing services, is there any further information about it? Do you have any further comments?	To address further possibly useful information about each cloud computing service

Multimedia Appendix 3: Taxonomy Development Iterations

Iteration	Approach	Data sources[a]
1	deductive	[1–4] i09; i16; i20; i21
2	deductive	[5–9] i12; i13; i24
3	inductive	C16; C25; C33; C39; C49; C50
4	deductive	[10–13] i04; i11; i18; i23
5	inductive	C01; C04; C07; C22; C23; C24; C40;
6	inductive	C14; C29; C34; C35; C46; C42
7	deductive	[14–17] i05; i08; i10; i22
8	inductive	C02; C05; C12; C15; C37; C41
9	deductive	[18–22] i02; i07; i14
10	inductive	C17; C20; C26; C28;C30; C44
11	inductive	C08; C11; C21; C31; C45; C48
12	deductive	[23,24] i01; i03; i06; i15; i17; i19;
13	inductive	C06; C09; C13; C32; C38; C43
14	inductive	C03; C10; C18; C19; C27; C36; C47

Note:

a. For data sources labelled with ‘i#’ cf. Table 1 in the paper. For data sources labelled with ‘C#’ cf. Multimedia Appendix 1

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Multimedia Appendix 4: Taxonomy of Cloud Computing Services (CCSs) for Health Care Organizations

CCS[a]	ST				SF			DM			TCA							T		U			SDD			PDI		
	cl	ad	sg	re	sw	pf	if	pb	pr	co	sc	el	ub	ce	sh	io	se	rt	nr	pa	ms	fm	ip	at	sp	in	ex	ni
C01	√				√			√			√					√			√		√		√			√		
C02	√	√			√			√			√		√						√		√		√			√		
C03	√				√			√			√				√	√			√		√		√				√	
C04		√			√			√					√		√				√		√				√		√	
C05	√				√			√			√		√					√		√	√				√		√	
C06	√					√			√		√			√			√		√		√		√			√		
C07	√				√			√			√		√		√				√	√	√			√		√		
C08	√		√		√			√					√		√		√	√			√			√			√	
C09	√				√				√							√			√		√			√		√		
C10	√				√				√				√		√			√		√	√				√		√	
C11	√				√			√			√			√					√		√		√			√		
C12	√				√				√		√				√				√		√		√			√		
C13	√				√				√				√		√				√		√				√	√		
C14	√				√			√			√			√					√		√		√			√		
C15	√			√	√			√			√		√			√		√			√		√				√	
C16	√				√			√			√		√					√		√	√				√		√	
C17	√				√			√			√				√				√		√				√	√		
C18	√				√				√		√		√		√				√		√			√		√		
C19		√			√				√		√					√			√		√		√				√	
C20	√				√			√					√		√		√	√			√			√		√		
C21	√				√			√					√		√		√	√			√			√		√		
C22		√	√		√			√			√								√		√		√			√		
C23	√				√					√	√				√				√		√		√			√		
C24	√	√	√	√	√				√			√	√	√					√		√		√			√		
C25	√				√					√	√				√		√		√		√		√			√		
C26	√	√			√				√				√						√	√		√			√		√	
C27	√				√				√				√		√				√		√				√	√		
C28		√					√		√			√						√			√		√			√		
C29		√			√				√				√						√	√		√			√		√	
C30	√				√				√				√		√				√		√				√	√		
C31	√				√			√			√			√					√		√		√			√		
C32		√			√			√	√		√							√		√			√			√		
C33	√				√					√	√				√		√		√		√		√				√	
C34	√				√			√			√		√					√		√	√				√		√	
C35	√	√	√	√	√			√			√			√					√		√		√			√		
C36	√	√	√	√	√				√			√	√	√					√		√		√			√		
C37	√	√	√	√			√	√			√	√		√				√			√		√			√		
C38	√						√		√		√			√			√	√			√		√			√		
C39			√		√			√			√								√		√		√			√		

Multimedia Appendix 4: Continued

CCS[a]	ST				SF			DM			TCA							T		U			SDD			PDI		
	cl	ad	sg	re	sw	pf	if	pb	pr	co	sc	el	ub	ce	sh	io	se	rt	nr	pa	ms	fm	ip	at	sp	in	ex	ni
C40	√				√					√					√			√			√		√				√	
C41				√	√			√			√					√	√	√			√			√		√		
C42		√			√			√								√	√	√			√			√			√	
C43	√		√		√				√		√				√			√			√		√			√		
C44		√		√	√			√			√				√			√			√		√					√
C45	√				√			√			√			√			√		√		√		√			√		
C46				√	√			√			√				√				√		√		√				√	
C47			√		√				√					√				√			√		√					√
C48		√			√			√			√								√		√		√					√
C49			√		√			√			√				√			√			√			√				√
C50	√	√	√	√	√			√					√		√			√			√			√		√		
Hits (N)	36	16	11	9	46	1	3	29	18	4	32	4	20	11	22	7	10	20	30	8	47	2	29	10	11	31	15	4

Abbreviations:
ad (Administrative); at (Adapted); CCS (Cloud computing service); ce (Cost efficiency); cl (Clinical); co (Community); DM (Deployment model); el (Elasticity); ex (External); fm (Family member); if (Infrastructure); in (Internal); io (Interoperability);
ip (Independent); ms (Medical staff); ni (No involvement); nr (Not real-time);
pa (Patient); pb (Public); PDI (Patient data involvement); pf (Platform); pr (Private);
re (Research); rt (Real-time); sc (Scalability); SDD (Service delivery device);
se (Security); SF (Service form); sg (Strategic); sh (Shareability); sp (Specialized);
ST (Supported task); sw (Software); T (Timeliness); TCA (Targeted cloud advantage); U (User); ub (Ubiquity)

Note:
a. For the descriptions of the cloud computing services (labelled with C#) cf. Multimedia Appendix 1

Multimedia Appendix 5: Taxonomy's Fulfilment of the Subjective Ending Conditions

Condition[a]	Definition	Justification for the fulfilment
Concise	The number of dimensions in a taxonomy should fall in the range of seven plus or minus two, such that the taxonomy is not overwhelming.	Our taxonomy is composed of eight dimensions.
Robust	A taxonomy should contain enough dimensions and characteristics to adequately differentiate the objects of interest.	In our taxonomy, each dimension is a distinct facet of a cloud computing service (CCS) and contains two to seven characteristics. The taxonomy yields a large number of characteristic combinations to differentiate among CCSs.
Compre-hensive	A taxonomy should classify all known objects within the domain or include all dimensions of objects of interest.	Although a complete evaluation of all existing CCSs in health care is not guaranteed, we provide a long list of existing CCSs that can be classified using our taxonomy. Our taxonomy was developed on the basis of studies covering a broad spectrum of topics about cloud computing that are applicable to empirical data from the expert interviews. Thus, the taxonomy covers a wide range of perspectives related to its meta-characteristic.
Extendible	A useful taxonomy permits the inclusion of additional dimensions and characteristics within a dimension if new types of objects appear.	Additional dimensions and/or characteristics can be easily added to our taxonomy (for example, if new CCSs are developed that provide novel service models for hospitals, their corresponding characteristics can easily be added to the dimension service form).
Explanatory	It should be clear what the taxonomy's dimensions and characteristics explain about an object.	Guided by how-to knowledge and principle knowledge, our taxonomy explains how CCSs can be used by hospitals and why they support hospitals.

Note:
a. The subjective ending conditions are according to Nickerson et al. [1]

References

1. Nickerson RC, Varshney U, Muntermann J. A Method for Taxonomy Development and Its Application in Information Systems. European Journal of Information Systems 2013;22(3):336-359. doi:10.1057/ejis.2012.26

Multimedia Appendix 6: Future Research Directions

Future research direction	Exemplary research questions
Explanation for the lack of IaaS and PaaS in health care	• Why is IaaS (or PaaS) lacking in health care settings?
Design and development of industry-specific IaaS (or PaaS)	• How can industrial IaaS (or PaaS) fulfill specific IT infrastructure (or platform) requirements in health care? • How can IaaS provide IT infrastructures to enable digital transformations in health care? • How/Why/Under what conditions does CC become a critical infrastructure for the health care industry?
Investigating adopter's awareness and perception of increased data security and interoperability through CC	• How can users be informed about the improved security and interoperability from CC for hospitals?
Identification of the factors that have industry-specific impacts on cloud adoption/acceptance	• What factors (of CC) have industry-specific impacts on cloud adoption in the health care industry?
Explaining the economic results of using CC	• How are the economic results of using CC related to the length of CC's use in health care organizations? • What factors influence the short-term/long-term economic results of CC in health care organizations? • What transformative value does CC have for health care organizations?
Enhancing (short-term) economic benefits of using CC	• How can cloud business processes be designed to improve CC's economic results in health care?
Investigating the ways CC supports care-related research	• What research activities in medical research can be supported by CC? • How does CC support the technologies used (eg, big data) in medical research?
Explanation the ways CC supports patient-centeredness	• When does the involvement of family members as cloud users support patient-centeredness in health care organizations?
Exploring how CC overcomes the limitations of mobile or small devices (eg, sensor networks) in health care	• How does CC support the use of pervasive computing technologies for health care?
Improvement and evaluation of CCSs that support collaboration in clinical activities	• What factors influence CC's capability to support collaboration in clinical activities?
Investigating how CC supports collaboration in areas other than clinical in health care	• How does CC support collaboration in health care organizations' administrative/ medical research activities?

3. Context Matters: A Review of the Determinant Factors in the Decision to Adopt Cloud Computing in Healthcare

Paper 2

Gao, Fangjian; Sunyaev, Ali (2018): Context Matters: A Review of the Determinant Factors in the Decision to Adopt Cloud Computing in Healthcare In International Journal of Information Management, under review.

Context Matters: A Review of the Determinant Factors in the Decision to Adopt Cloud Computing in Healthcare

Abstract

Cloud computing is an emerging IT service paradigm that can enhance traditional health IT approaches and offer major benefits to the healthcare industry, if used meaningfully. However, its adoption by healthcare organizations has been accompanied by diverse challenges that could impede its meaningful use. Decisions about its adoption deserve serious consideration of relevant industry-specific factors. Whereas the research has focused on cloud computing adoption in general, the industrial specificities that influence the decision to adopt cloud computing in the healthcare context have yet to be systematically addressed. We reviewed empirical studies in both information systems and medical informatics to investigate the determinant factors of the cloud computing adoption decision in healthcare organizations and those factors' industrial specificities. Based on the results of our review, we proposed a conceptual model of cloud computing adoption studies in healthcare and made seven recommendations for related future research. Our research contributes to theory by providing a comprehensive list of industry-specific factors that influence cloud computing adoption decisions in healthcare and explains their specificities for the healthcare industry. For practitioners, the identified factors serve as a checklist that informs healthcare organizations' decision making regarding cloud computing adoption.

Keywords: cloud computing; health IT; adoption; IT outsourcing; IT innovation

Abbreviations: application service provision (ASP); cloud computing (CC); cloud computing services (CCS); diffusion of innovations (DOI); Hawaii International Conference on System Sciences (HICSS); human, organization and technology-fit (HOT-fit); infrastructure as a service (IaaS); information systems (IS); IT innovation (ITI); IT outsourcing (ITO); medical informatics (MI); platform as a service (PaaS); software as a service (SaaS); technology-organization-environment (TOE)

1. Introduction

Cloud computing (CC) is an emerging innovative IT service paradigm that enables users to gain on-demand network access to a shared pool of configurable computing resources, such as servers, storage, and applications (Mell & Grance, 2011). The IT services provisioned by CC (i.e., cloud computing services (CCSs)) are web-based and can be rapidly released with minimal management effort (cf. section 2). Thus, CC presents “a fundamental change” (p. 176) in how IT services are developed, deployed, maintained, and paid for (Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011). If applied properly, CCSs can provide various benefits for numerous organizations (e.g., Sabi, Uzoka, Langmia, & Njeh, 2016; Dwivedi & Mustafee, 2010; Jones, Irani, Sivarajah, & Love, 2017), including those from the healthcare industry that provide care-related goods and services (Benlian, Kettinger, Sunyaev, & Winkler, 2018; Gao, Thiebes, & Sunyaev, 2018; Meri, Hasan, & Safie, 2018). If used in a meaningful way (i.e., where CC provides constructive support; Nelson & Staggers, 2018), CC allows healthcare organizations (i.e., hospitals or clinics) with insufficient IT resources/infrastructure to easily access the required IT services through a network, which is based on a pay-as-you-go pricing model; CC enables healthcare organizations with a shortage of health IT staff (which is a general challenge currently in the healthcare industry; Zieger, 2017) to deploy IT resources to meet ever-changing medical demands in a timely manner, imposing only a minimal workload on their own IT staff (Gao et al., 2018). Therefore, CC serves as a strong enhancement to traditional health IT and provides great value to healthcare organizations (Benlian et al., 2018; Gao, Thiebes, & Sunyaev, 2016; also cf. section 2). Practitioners have called for a massive acceleration of CC adoption in the healthcare industry (Joch, 2017; Linthicum, 2017; Pratt, 2017).

A recent survey demonstrates that an increasing number of healthcare organizations intend to adopt CCSs and thereby benefit from the advantages of CC (HIMSS, 2016). However, CC is also accompanied by diverse challenges for healthcare organizations, particularly with respect to their management (e.g., difficulties in conducting IT audits), technology (e.g., data transfer bottlenecks), security (e.g., privilege abuse), and legal aspects (e.g., applicable law for service contracts) (Kuo, 2011). Healthcare organizations are characterized as highly intricate because of the operational complexity of medical services (Singh & Wachter, 2008), and the healthcare context involves different stakeholders with different interests (Standing & Standing, 2008) and possesses industry-specific features (cf. the next paragraph). Therefore, the phenomenon of CC in healthcare is complex, and its meaningful use by healthcare organizations can be ensured only under certain conditions (cf. Gao et al., 2018). While making decisions to use CCSs (i.e., CC adoption decisions), healthcare organizations should exercise considerable judgment and consider various determinant factors related to those conditions. An adoption decision made without serious consideration of these determinant factors could not only hinder the meaningful use of CC by healthcare organizations but also introduce difficulties: in a recent case, a careless CC adoption decision by a large UK hospital did not lead to expected benefits but rather to a £ 8.6 million financial deficit and even a temporary inability to deliver adequate medical services (Mathieson, 2015; Moore-Colyer, 2015), resulting in patients “being put at risk” (BBC, 2015).

The phenomenon of CC adoption has attracted the attention of the information systems (IS) community (e.g., Hsu, Ray, & Li-Hsieh, 2014). According to recent reviews, a very high proportion of IS studies about CC have focused on factors that influence and thereby explain the adoption decision of CC (Bayramusta & Nasir, 2016; Senyo, Addae, & Boateng, 2018). However, many of these studies are limited to general contexts or with minimal industrial or contextual considerations (Schneider & Sunyaev, 2016; also cf. section 2). Although some studies have taken the first steps toward the investigation of CC adoption specifically in the healthcare industry (e.g., Bernsmed, Cruzes, Jaatun, Haugset, & Gjaere, 2014; Lian, Yen, & Wang, 2014), these first attempts rely on related research from general contexts or only address the specificities of the healthcare industry in a fragmented manner. The specificities that affect CC adoption in the healthcare industry therefore remain under-addressed. The healthcare industry presents a markedly different context than other industries in which IS research has been conducted (e.g., manufacturing, transportation, financial services; Chiasson & Davidson, 2004). For example, the industry is operationally complex and highly institutionalized (Scott, 2005); healthcare organizations exist in different forms (e.g., for-profit, not-for-profit, government, private for-profit, private not-for-profit) with different motivations and interests (Chiasson & Davidson, 2004); healthcare organizations usually feature a dual administrative system of medical personnel and administration (Chiasson & Davidson, 2004). Furthermore, health reimbursement and the related financial resources often depend on external insurers or agencies with their own concerns and agendas (Singh & Wachter, 2008). These specificities, which are difficult to find in a general context, could heavily influence CC adoption in the healthcare industry (Gao et al., 2018). It is not surprising that factors from general contexts or other industries are regarded as insufficient to explain CC adoption in a context with unique contextual characteristics, such as the healthcare industry (Lian et al., 2014; Schneider & Sunyaev, 2016). The insufficient understanding of these specificities could therefore impede an effective investigation of the phenomenon of CC adoption in the healthcare industry.

In response to the identified research gap, this paper strives to answer the following research questions: *What factors influence CC adoption decisions in healthcare organizations? How do these factors influence the CC adoption decision? What specificities do these factors have regarding the healthcare industry?* To answer these research questions, we conducted a review of the related empirical literature from both IS and medical informatics (MI) publication outlets to provide evidence of CC adoption in healthcare. Because CC is an emerging phenomenon in the healthcare industry, we viewed CC as a derivative of IT outsourcing and as a representative of IT innovation in healthcare (cf. section 2). Our literature review not only focuses on CC adoption in healthcare per se but also relies on studies of IT outsourcing and IT innovation adoption in healthcare that can have implications for CC adoption. We expect to synthesize related knowledge from literature that was fragmented to advance our understanding of the specificities of CC adoption in the healthcare industry in a holistic manner. After reviewing 67 research studies, we identified five categories with 124 variables that could influence CC adoption in healthcare organizations. Of the identified variables, 40% (n=47) are industry-specific. Based on the results of our review, we propose a conceptual model to advance IS researchers' understanding of industrial specificities of CC adoption in healthcare and make seven recommendations for future research. Our research makes theoretical contributions by providing a list of industry-specific variables that influence the decision to adopt CC in healthcare. With the proposed conceptual model, we generalize the characteristics of the identified industry-specific variables and thereby explain the specificities of determinant variables for CC adoption in healthcare. Our study thereby advances the conceptual understanding of the specificities of CC adoption in the healthcare industry.

2. Theoretical Background

2.1. Health IT and Cloud Computing

Health IT and related computer-based data/information have the potential to improve the productivity and quality of healthcare services and therefore are considered crucial to the success of healthcare (Mandl & Kohane, 2017). However, traditional health IT approaches, in which healthcare organizations make or buy and maintain in-house software applications and hardware infrastructures, are often insufficient to fulfill the ever-changing and increasing needs in healthcare. Healthcare organizations, particularly in rural areas, often struggle with a scarcity of IT resources, such as computing or storage capacity (Mason, Mayer, Chien, & Monestime, 2017). Insufficient off-site access to or inflexible deployment of in-house IT infrastructure restricts healthcare organizations' ability to address changing IT demands caused by medical emergencies (Yao et al., 2014). Furthermore, the time consuming and costly maintenance of existing information systems and shortage of skilled health IT staff make IT a burden for healthcare organizations (Yao et al., 2014).

With its unique IT service paradigm, CC can enhance traditional health IT approaches. According to Mell and Grance (Mell & Grance, 2011), the most acknowledged definition of CC in the domain of IS, CC provides three service models: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). Therefore, CC can deliver either fundamental IT resources (through IaaS), IT platforms with programming languages, tools, and/or libraries for the software development or deployment (through PaaS), or ready-to-use software applications that run on cloud infrastructure (SaaS) to healthcare organizations. Moreover, CC relies on four deployment models (i.e., public; private; community; hybrid) to provide IT infrastructure that enables service delivery. In a public cloud, the CCS infrastructure is provided for open use by the general public, and the infrastructure of a private or community cloud is provisioned for the exclusive use of either a single organization or a specific group of organizations. A hybrid cloud is a combination of two or more of the aforementioned deployment models. The service paradigm enables CCSs to possess five unique essential technical features: on-demand self-service, resource pooling, rapid elasticity, broad network access, and measured service (see Table A.1 in appendices). As highlighted in Table A.1, these technical features enable CC to alleviate the aforementioned insufficiencies of traditional health IT approaches.

2.2. Duality of Cloud Computing Characteristics in Healthcare

CC and its adoption as a health IT artifact are complex IT phenomena (Kuo, 2011) and thus deserve reflection from different conceptual angles (Nickerson, Varshney, & Muntermann, 2013). Based on key characteristics of CC, we adopt a dual view for this research to conceptualize CC and its adoption in healthcare organizations. This dual view incorporates CC as a derivative of IT outsourcing and CC as a representative of IT innovation.

2.2.1 Cloud computing as a derivative of IT outsourcing

Numerous IS research studies have explained that CC and IT outsourcing (ITO) share common characteristics (e.g., Lang, Wiesche, & Krcmar, 2018). In particular, CC is argued to be similar to application service provision (ASP) and SaaS of ITO (Benlian, Koufaris, & Hess, 2011; Vithayathil, 2017). IS researchers have compared CC with ITO and highlighted the similarities between the two concepts (e.g., Leimeister, Böhm, Riedl, & Krcmar, 2010).

From the health IT perspective, CC is also regarded as a specific form of ITO (Hucíková & Babic, 2016). In health IT, ITO refers to the transfer of responsibility for providing IT services to an external provider (Reddy, Purao, & Kelly, 2008). CC has four deployment models: public, private, community, and hybrid. Although the public cloud is well recognized as ITO because of its off-premise nature, IT infrastructures of private and community clouds are often misunderstood as being on the premises of cloud users. Based on Mell & Grance (2011), private and community clouds may also exist off cloud users' premises, which makes the entire concept of CC more similar to ITO. It must be stressed that although theorists recommend the use of (partially) on-premises CCSs by the healthcare industry for reasons related to data privacy and security issues (Ermakova, Fabian, & Zarnekow, 2017), we are aware of few IT adoption studies that discuss CCSs with an on-premises IT infrastructure in the healthcare (or other) industry. This finding is probably because off-premises CCSs enable adopters to utilize their essential technical features to a greater extent (Kilcioglu, Rao, Kannan, & McAfee, 2017). Hence, research findings on ITO adoption are applicable to CC adoption in the healthcare industry, which has been proven by previous research (e.g., Chen & Wu, 2013). We argue that it is meaningful to observe CC from the ITO perspective, and CC is deemed a derivative of ITO in the context of this research.

2.2.2 Cloud computing as representative of IT innovation

An innovation can be defined as an idea, practice, or object that is perceived as new by an individual or group (Rogers, 2003). In the context of healthcare, three types of innovation can be observed (Herzlinger, 2006): 1) innovation focusing on how consumers buy and use healthcare; 2) innovation applying technology to improve products, services or care; and 3) innovations generating new business models. By definition, CC is a new practice of applying information technology in healthcare organizations (type 2), because it is in sharp contrast to traditional health IT patterns, in which organizations make or buy and maintain in-house software applications and hardware infrastructures (Dwivedi & Mustafee, 2010).

Although the concept of CC has existed for nearly ten years (Sultan, 2013), it remains recognized as a highly innovative IT artifact by healthcare organizations (e.g., Fernández, 2017; Gao et al., 2018; Ozkan, 2017). This finding is attributable to the specificity of the healthcare industry in IT adoption. Healthcare organizations have been proven to traditionally act as laggards in IT innovation (ITI) adoption (Cicibas & Yildirim, 2018; Sulaiman & Wickramasinghe, 2018). Rogers (2003) explains that such organizations become aware of ITI (and the related characteristics/benefits) extremely late. Moreover, it must be stressed that the adoption of CCSs can provide flexible IT infrastructure and thus opportunities for healthcare organizations to apply other sophisticated information technologies (Jaatun, Pearson, Gittler, Leenes, & Niezen, 2016). Certain researchers claim that CC has become the key enabler of digital transformation in the healthcare industry (Abolhassan, 2017; Bhavnani et al., 2017). Although it is by no means necessary to overvalue the role of CC in healthcare, the essential technical features of CC, particularly *resource pooling*, *rapid elasticity,* and *broad network access*, ensure the necessary IT resources and access to different devices. These are basic conditions for the implementation of most ITIs in healthcare, such as artificial intelligence, big data, and sensor technology. Thus, a very high proportion of existing CCSs in healthcare is found to combine with emerging technologies (e.g., Esposito, De Santis, Tortora, Chang, & Choo, 2018; García, Tomás, Parra, & Lloret, 2018; Zhang, Qiu, Tsai, Hassan, & Alamri, 2017) and provides the most innovative IT services to healthcare organizations.

Based on the argument set above, we summarize by stating that CC can be viewed as a representative of ITI for healthcare organizations; in addition, it is meaningful to observe CC adoption in healthcare from an ITO perspective.

2.3. Related Research

To the best of our knowledge, four literature review studies are related to this research.

Ermakova, Huenges, Erek, & Zarnekow (2013) provided a review of existing studies on CC that are related to healthcare from an IS perspective. The researchers' review identifies the state of the art in CC research in healthcare. According to Ermakova et al. (2013), existing research studies heavily focus on the development of specific IT artifacts that are based on or related to CC or address the privacy and security challenges of CC in healthcare. Ermakova et al. (2013) do not discuss the topic of CC adoption in healthcare.

In a more recent literature review study on CC in healthcare, Griebel et al. (2015) investigated research articles about CC from an MI perspective. Similar to Ermakova et al. (2013), Griebel et al. (2015) revealed that research studies in MI mainly targeted providing specific applications that are based on CC. Griebel et al. (2015) have also delivered minimal focus on the adoption of CC in healthcare.

In a more common context, the topic of CC adoption has attracted more attention from researchers, according to the literature review study of Schneider & Sunyaev (2016). By adopting an ITO perspective for CC adoption, Schneider & Sunyaev (2016) investigated 88 empirical IS studies. Although the researchers identified a set of determinant factors for CC adoption, these factors nearly only originate from contexts other than healthcare. Therefore, these factors are not suitable for CC adoption issues in the healthcare industry, particularly because Schneider & Sunyaev (2016) recognized that different industries have different specificities concerning CC adoption, and the healthcare industry deviates substantially from industries that have been traditionally studied by IS, as described in section 1.

Finally, the literature review by Jeyaraj, Rottman, & Lacity (2006) provided an overview of research studies on ITI adoption, which is related to our discussion of CC in healthcare from an ITI perspective. Those researchers' review covered both individual and organizational adoption of ITI and delivered a list of predictors related to the ITI adoption decision. Similar to Schneider & Sunyaev (2016), the identified predictors in Jeyaraj et al. (2006) are limited to contexts other than healthcare. It must be stressed that Jeyaraj et al. (2006) also found that the specificities of an organization's industry or sector have an impact on the ITI adoption decision.

3. Research Method

We conducted a review of the research literature on the adoption of CCSs in healthcare. Our review's objective is to identify independent variables (with their effects) that could influence the decision to adopt CC in healthcare organizations. We drew on acknowledged literature review methods in IS that have been employed by previous high-quality studies closely related to our study (e.g., Jeyaraj et al., 2006; Lacity, Khan, Yan, & Willcocks, 2010; Rana, Williams, Dwivedi, & Williams, 2012; Schneider & Sunyaev, 2016) to design our literature review approach because these methods specifically assist us to derive independent variables (with their effects) for IT adoption decision. We describe our method in detail in this section.

3.1. Literature Search

For our literature search, we acted in accordance with the guidelines of Webster & Watson (2002) to ensure high-quality sources of literature. According to Webster & Watson (2002), the major contributions in a particular research field are most likely to be found in high-quality journals with a strong reputation. This research, which addresses a topic in health IT, is related to IS and MI research. Accordingly, we started our literature search with IS and MI publication outlets that have been highly regarded, which was complemented by additional forward and backward searches. For IS, we included the Senior Scholars' Basket of Journals (Association for Information Systems, 2011), the top 50 journals in the AIS journal ranking (Association for Information Systems, 2005), including selected ACM/IEEE Transactions based on Schneider & Sunyaev (2016), along with leading healthcare-related IS journals, according to Chiasson & Davidson (2004). For MI, we selected the 44 most acknowledged journals in health IT as suggested by Le Rouge & De Leo (2010), the top 20 journals in the MI category according to Google Scholar (2016), and two leading journals (*New England Journal of Medicine* and *Journal of the American Medical Association*) from the medical discipline that can provide insights into the medical field's discussion of MI (Weigel, Rainer, Hazen, Cegielski, & Ford, 2013). Because CC is an innovative topic in healthcare, we also included the top three conferences of the IS (Schneider & Sunyaev, 2016) and MI communities (Le Rouge & De Leo, 2010) to cover the latest research. After removing duplicates, we generated a final list of 79 IS journals, three IS conferences, 50 MI journals, and two MI conferences (see Table S.1 in supplementary material for a full list of the journals and conferences included). *Hawaii International Conference on System Sciences* (HICSS) is suggested as one of the top conferences in both IS and MI. We classified HICSS as an IS conference for this research because its papers are not limited to MI-relevant topics.

We applied the dual view of CC characteristics (i.e., ITO and ITI) and searched publications by *title*, *keywords*, and *abstract*. We used the following list of keywords for the IS journals and conferences to focus on research studies on the topics of CC, ITO and ITI in healthcare organizations: (*cloud* OR '*software as a service*' OR '*platform as a service*' OR '*infrastructure as a service*' OR '*software-as-a-service*' OR '*platform-as-a-service*' OR

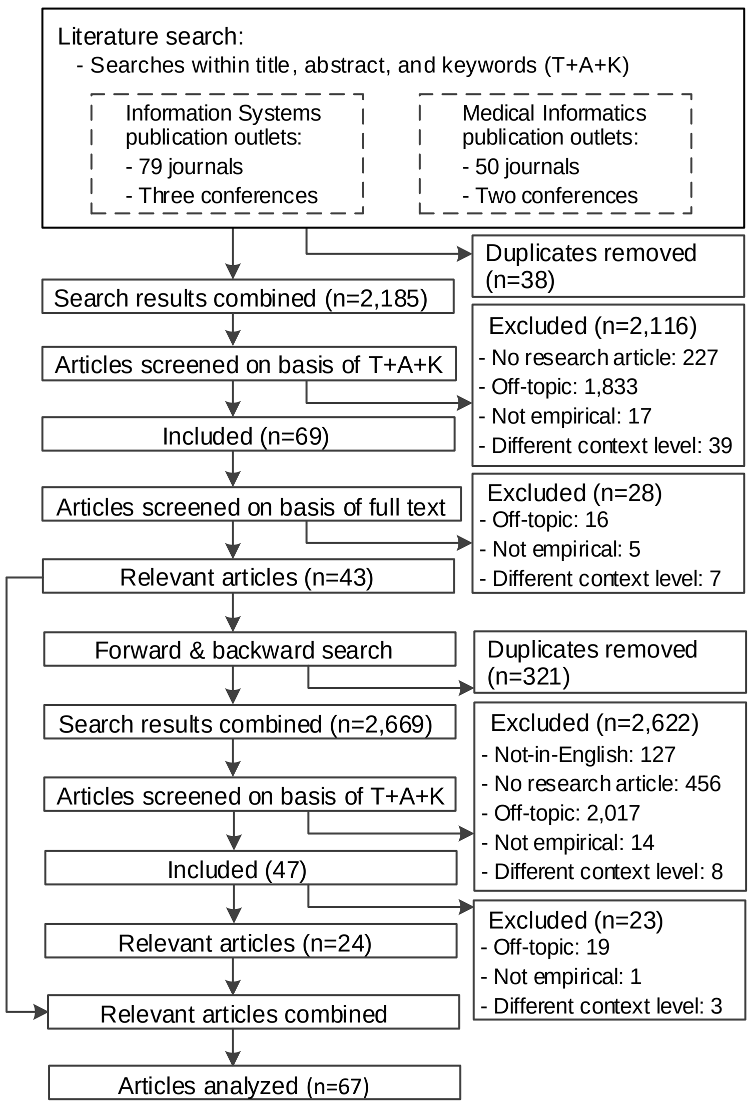

Figure 1 Overview of literature review process

‘*infrastructure-as-a-service*’ OR *SaaS* OR *PaaS* OR *IaaS* OR ‘*application service*’ OR *ASP* OR *outsourc** OR *offshor** OR *innovat**) AND (*hospital** OR *clinic** OR **health** OR *nurs** OR **medic** OR **patient**). For the MI journals and conferences, we only used the first half of the keywords in the list (i.e., we ignored ‘AND (*hospital** OR *clinic** OR *health** OR *nurs** OR **medic** OR **patient**)’) because the scope of the MI publications guarantees that search results are within the thematic area of healthcare. Table S.1 delivers an overview of the search engines we used. The literature search process was conducted in September 2016. Figure 1 delivers an overview of our literature review process. After removing duplicates, a sample of 2,185 articles remained.

3.2. Literature Identification

To identify relevant studies for further analysis, we developed exclusion criterion based on our research purpose. Our research focuses on completed articles that empirically investigate IT adoption with respect to CC, ITO, or ITIs in healthcare organizations. Therefore, we excluded articles if they 1) are *no research articles* (e.g., editorial comments); 2) are not about the topic of ‘adoption’ of CC, ITO, and ITI, which is relevant for our research (*off-topic*); 3) are not empirical studies (*not empirical*; e.g., Guah & Currie, 2003); or 4) do not focus on the organizational adoption of IT (*different context level*: Choudrie & Dwivedi (2005) demonstrate that IS studies related to IT adoption differ between organizational level and individual level; Dünnebeil, Sunyaev, Blohm, Leimeister, & Krcmar (2012) who focused on an individual-level has for example been excluded). Because we regarded CC as derivative of ITO, we made a special effort to use the *off-topic* criterion to filter IT adoption studies about CCSs that have IT infrastructures on the premises of the healthcare organizations. To ensure the applicability of articles concerning ITO to CC, we followed Schneider & Sunyaev (2016) and relied on the descriptive ITO framework of de Looff, Leon A (1995) to only include ITO articles about selective outsourcing of at least the maintenance and operation of the hardware or software of any functional information system to an external provider while keeping the business process in-house, which is the core use of CC in healthcare (Kuo, 2011). Research focusing on, for example, software development, help desk, or business process outsourcing is not within the scope of our literature review. Similarly, we employed the descriptive ITI framework of Herzlinger (2006) to only include ITI articles about the new practice of applying information technology in healthcare organizations. Accordingly, research about emerging patterns of healthcare consumption and new business models that do not consider the use of IT were excluded.

The screening process consisted of two sub-steps that were separately conducted by two researchers. After each step, two researchers compared their results, and differences were resolved through discussion. In the first sub-step, articles were screened using title, abstract, and keywords. Both researchers successively applied the four pre-defined exclusion criteria to each of the identified articles. After first sub-step, 2,116 articles were excluded from further consideration. Thereafter, two researchers separately screened the remaining articles by reading the full text and successively applying the pre-defined exclusion criteria. Twenty-eight articles that were *off-topic*, *not empirical*, or had a *different context level* were further excluded in this sub-step. Finally, 43 articles remained after the screening of the literature identified from the IS and MI publication outlets.

In accordance with Webster & Watson (2002), we conducted a forward and backward search on the relevant articles. We identified 2,669 further articles (with duplicates: n=2,990) that either cited one of the 43 relevant articles (i.e., forward search) or were cited in one of these articles (i.e., backward search). Thereafter, two researchers screened the 2,669 articles using the same screening process described above. We noticed that a few newly identified articles (in particular, by forward search) were not in English. Therefore, we applied an exclusion criterion *not-in-English* to the 2,669 articles before further exclusion criteria could be employed. As shown in Figure 1, 24 additional articles were found to be relevant to our research, 11 of which were identified using the forward search and 13 of which were identified using the backward search. Consequently, 67 articles were identified as relevant to this research and were analyzed in detail.

3.3. Literature Analysis

The literature analysis consisted of three sub-steps. In the first step, we coded all 67 relevant articles. To ensure a structured analysis of the literature, we developed a coding scheme and thus provided a solid basis for our research (Webster & Watson, 2002). The coding scheme contains three blocks, as explained in Table 1. The first block (see I01-I04 in Table 1) was used to capture the relevant articles' meta-information. Accordingly, this capture included items to describe each article's profile, including *research domain*, *research method*, and *research type*. The second block (see I05-I06 in Table 1) was oriented toward Chiasson & Davidson (2004) and examined the use of IS theories in the reviewed articles. According to Chiasson & Davidson (2004), the high value of a (health IT) research study for the IS community lies in its use of theories to explain the IT phenomena of interest, which has been confirmed by further researchers (e.g., Dwivedi, Wade, & Schneberger, 2012; Rana et al., 2012). We used this second block to record how the reviewed studies applied theories to explain the phenomenon of IT adoption (including CC, ITO, and ITI) and to guide the use of related concepts. We thus targeted insights into the conceptual use of these

Table 1 Overview of the coding scheme

	ID	Item	Possible value(s)	Purpose and Description
Block 1	I01	Research domain	*information systems* or *medical informatics*	To identify whether a research study originates from the domain of information systems or of medical informatics
	I02	Research type	*qualitative*, *quantitative*, or *mixed*	To classify which type of empirical research methods the research study conducted
	I03	Research method	Include but are not limited to, *survey*, *experiments*, *case study*, or *interviews*	To describe the specific research method(s) used in the research paper
	I04	Research view	*cloud computing*, *IT outsourcing*, or *IT innovation*	To identify which topic in the triple view of cloud computing characteristics the research study addressed
Block 2	I05	Theory used	For example: *contingency theory*, *institutional theory*	To capture theory(ies) that was (were) used and/or developed by the research study (based on Chiasson & Davidson (2004))
	I06	Theoretical focus	*IS* (information systems) *only*, *IS-Healthcare*, *Healthcare-IS*, or *Healthcare-only* (based on Chiasson & Davidson (2004))	To identify whether the theoretical focus of the paper is on testing or refining existing IS theories without regard for the healthcare context (*IS only*), on testing or refining existing IS theories with some regard for the healthcare context (*IS-Healthcare*), on examining phenomena in the healthcare context and using theory to explain or build/expand theory in this context (*Healthcare-IS*), or on describing IS or IT in healthcare context with little consideration of theory (*Healthcare-only*)
Block 3	I07	Dependent variable	For example: *cloud adoption*, or *IT outsourcing decision*	Based on Jeyaraj et al. (2006), to capture dependent variable(s) that appeared in the research study with its(their) definition(s)
	I08	Independent variable	For example: *organization size*, or *top management support*	Based on Jeyaraj et al. (2006), to capture independent variable(s) that appeared in the research paper with its(their) definition(s)
	I09	Relationship	*+1*, *-1*, *M*, or *0* (based on Jeyaraj et al. (2006))	To record the relationship between a dependent variable and an independent variable; *+1*: the independent variable is positively associated with the dependent variable[1]; *-1*: the independent variable is negatively associated with the dependent variable[1]; *M*: the relationship between the dependent variable and the independent variable is significant but non-directional[1]; and *0*: the relationship was investigated but a significant relationship was not found and hypothesis cannot be supported

Note.
1: This result is statistically significant and/or supports the related hypothesis for a quantitative study; this result is based on a strong argument for a qualitative study.

studies in healthcare. The third block focused on factors that influence CC/ITO/ITI adoption in healthcare organizations.For this block, the coding method of Jeyaraj et al. (2006) was applied to record the dependent (Table 1, I07) and independent variables (Table 1, I08) for CC/ITO/ITI adoption and their relationships (Table 1, I09) for each of the articles. Table 1 summarizes the coding scheme and delivers an explanation/justification for each item. We applied the defined coding scheme to the 67 relevant articles. To ensure a consistent analytical result, two researchers independently coded all the articles. Thereafter, the coding results were compared and aggregated, and the two researchers discussed and resolved any conflicts.

In the second sub-step, in accordance with Schneider & Sunyaev (2016), we generated a list of *master variables* with *master variable definitions*. The purpose of this sub-step is to provide an aggregated list of independent variables from the previous sub-step. A *master variable* (e.g., *organization size*) serves as a term that covers all the variables we addressed from the literature with identical or similar definitions or for the same purpose (e.g., *hospital scale*, *number of beds*). Two researchers separately reviewed the coded variables from the first iteration. For each coded variable, each researcher checked whether there was previously a *master variable* that could cover the coded variable based on a comparison of their definitions; if so, the coded variable was added to the list under this *master variable*. The designation of the *master variable* and the related *master variable definition* were refined if needed. Otherwise, the reviewed coded variable was defined as a new *master variable* in the master variable list. Thereafter, the two researchers compared and aggregated their *master variables* and the *master variable definitions*. In addition, they reviewed and discussed all coded variables covered by each master variable and their relationships (Table 1, I09) with the independent variables to finalize the *master variable* list. The final *master variable* list with the *master variable definitions* are presented by Table S.2 in supplementary material.

In the third sub-step, we categorized the *master variables* based on their *master variable definitions*. The purpose of this sub-step is to provide a structured overview of the *master variables*. Thus, we sought to obtain insights into the conceptual use of the determined *master variables* and to address the third research question. We relied on three fundamental concepts from the recorded theories that have previously been applied by the reviewed articles to categorize the *master variables*. Although many of the *master variables* can be categorized using these three fundamental concepts, certain variables remained uncategorized. For these *master variables*, we employed Bailey's (1994) inductive classification, which is well established in IS (e.g., Nickerson et al., 2013), to derive categories. The basic idea of Bailey's (1994) method is to review empirical data that should be classified (i.e., the *master variables*) and inductively conceptualize the nature of these data as categories. We classified all remaining *master variables* according to their conceptual commonalities and differences in the *master variable definitions* (Bailey, 1994) into two categories. For each category, we derived a term that conceptually covered the belonging *master variables* and their *master variable definitions*.

As mentioned above, the literature analysis (as well as literature identification and screening) followed the best practices used in previous research. This method ensures the identification of relevant variables that affect CC adoption by healthcare organizations in an effective manner.

4. Research Findings

4.1. Overview of the Reviewed Articles

Of the 67 reviewed articles, 35 articles originate from IS publication outlets, and the remaining 32 articles are from MI. The 35 IS articles are spread over 26 journals or conference proceedings, and the 32 MI articles originate from 15 journals or conference proceedings. Ten of the reviewed articles focus on the topic of CC adoption; 16 address the ITO decision, and 41 refer to ITI adoption by healthcare organizations. Of the 67 articles, 30 use quantitative research methods and 32 use qualitative research methods; the remaining five articles rely on a mix of both types of methods.

In all, we identified 501 relationships related to the dependent variables that represent the adoption of CC, ITI or ITO by healthcare organizations. For the activity in which healthcare organizations engage when choosing to adopt IT artifacts (i.e., the dependent variable), we identified different expressions from the reviewed articles (e.g., *acquisition*: Baker, Song, Jones, & Ford, 2008; *adoption*: Tsiknakis & Kouroubali, 2009; *decision*: Lorence & Spink, 2004; *purchasing decision*: Mills, Vavroch, Bahensky, & Ward, 2010). All of these expressions represent an organization's decision or intention to adopt an IT service or product. We summarize these expressions by using a meta-dependent variable—*adoption*—for this study. The 501 relationships were aggregated into 124 *master variables* that have an impact on the *adoption* of CC/ITI/ITO by healthcare organizations.

4.2. The Five Categories of the Master Variables

We identified five categories of the identified *master variables*. As described in section 3, although the first three categories reflect traditional IT adoption theories, the remaining two categories are not encompassed by traditional theories.

Among the 67 reviewed articles, we found that only 33 of them employed established theories to guide their empirical studies, thereby delivering insights into the application of theories to the adoption of CC/ITO/ITI in healthcare. We found that the *technology-organization-environment (TOE) theory* of DePietro, Wiarda, & Fleischer (1990) (10 times) and the *diffusion of innovations (DOI) theory* of Rogers (2003) (9 times) are the main theories employed in the reviewed articles. The TOE theory explains that the main factors that influence the decision of an organization to adopt IT are *technological*, *organizational* and *environmental* aspects that present "both constraints and opportunities" (p. 154) related to the adoption of IT (DePietro et al., 1990). The *technological* aspect concerns IT characteristics, which also include related IT processes. The *organizational* aspect describes the characteristics of the organization that intends to adopt IT, whereas the *environmental* aspect refers to the context and surroundings of the organization. The DOI theory mainly describes innovation adoption and diffusion processes (Rogers, 2003). In this regard, the characteristics of the adopted innovations (i.e., IT) and the adopters (i.e., organizations) have been recognized as crucial for the innovation adoption process, which is in line with the TOE theory. In addition, our review shows that theories focusing on resources (i.e., *resource-based theory*: Barney, 1991; *resource dependency theory*: Pfeffer & Salancik, 2003; *theory of internal resource allocation*: Pondy, Starbuck, & Walter, 1970) for healthcare organizations are also frequently used to explain the adoption of CC/ITI/ITO by healthcare organizations (4 times). Although these theories have different assumptions and/or specifications (cf. Cheon, Grover, & Teng, 1995), they have been used in the reviewed articles to explain the importance of (internal and/or external) *resources* that are related to the adoption of CC/ITI/ITO (e.g., Kazley & Ozcan, 2007; Leidner, Preston, & Chen, 2010). By definition, the *technological* and *environmental* aspects of the TOE theory cover both internal and external resources of the organization (DePietro et al., 1990). Accordingly, we specified *technology*, *organization*, and *environment* as the three basic categories of the core concepts embodied by the TOE theory, the DOI theory and theories focusing on resources.

The classification of the remaining *master variables* that are not covered by the three basic theoretical categories yielded two additional categories: *data/information* and *stakeholders*. The implications of both of these categories are addressed in section 5.

4.3. Determinant Factors for CC Adoption in Healthcare

The 124 *master variables* are presented alongside the five categories. We focus on the *master variables* that can provide insights into CC adoption in healthcare. As discussed above, CC in healthcare possesses ITO and/or ITI characteristics. Based on Lacity et al. (2010), we regard a *master variable* as able to provide insights only if it has *consistent empirical results* jointly in at least two types of the CC, ITO, and ITI adoption studies and respectively in each of these two types. In accordance with Schneider & Sunyaev (2016), we regard a master variable as *consistent* if at least 60% of its empirical results are congruous (i.e., *positive*, *negative*, or only *significant*; Table 1, I09). These criteria ensure that the *master variable* can provide valid insights into CC adoption in healthcare from an ITO perspective (jointly and respectively in CC and ITO: evidence reflecting the ITO characteristics, which is applicable to CC), an ITI perspective (jointly and respectively in CC and ITI: evidence reflecting the ITI characteristics, which is applicable to CC), or an ITO and ITI perspective (jointly and respectively in ITO and ITI: evidence reflecting characteristics of an innovative ITO, which is applicable to CC). If this *master variable* has been studied *multiple times* (five times, based on Schneider & Sunyaev (2016)) in studies in which consistent evidence can be observed, it is defined as a *reliable* determinant factor for CC adoption in healthcare. Otherwise, this variable is viewed as a *potential* determinant factor. The multiple investigation requirement (i.e., studied five times) ensures the high robustness of the determinant factor and therefore its *reliability* (Lacity et al., 2010). Although *potential* determinant factors lack high robustness, they can inform future research, as set forth in section 5. Although we identified a small number of *master variables* (n=7) that have been only examined in the context of CC, they either cannot deliver consistent empirical results (e.g., *uncertainty about vendor's stainability*) or have only been examined once (e.g., *system quality*). Thus, these variables are not sufficient to deliver meaningful, conclusive insights into CC adoption in healthcare. Table 2 delivers an overview of the identified categories and the *reliable* and *potential* determinant factors. A full list of all the identified *master variables* and their relationships with the *adoption* of CC/ITO/ITI can be found in Table S.2 in supplementary material.

Category: *technology*. This first category summarizes the *master variables* that refer to characteristics of the to-be-adopted technology or IT service and the expected effects and consequences of its use. Variables that belong to the *technology* category have been studied 103 times, resulting in 26 *master variables*. The most-examined *master variables* are *compatibility* (16 times), followed by *relative advantages* (14 times; cf. Table A.2).

As shown in Table 2, two *master variables*, namely, *improvement of quality of care* (e.g., Lorence & Spink, 2004) and *improvement of finances* (e.g., Harrop, 2001), are identified to deliver *consistent* and *robust* empirical results, serving as *reliable* determinant factors for CC adoption in healthcare. Both determinant factors are related to the expected results of the IT adoption and indicate positive empirical results. Similarly, the *master variable* that investigates whether the IT artifact to be adopted is in compliance with related IT standards (*compliance with standards*; e.g., Hunter, Krupinski, & Weinstein, 2013) is also found to have a consistent positive effect for CC, ITO and ITI. However, this result is not robust, and it serves as a *potential* determinant factor. The determinant factor *uncertainty about reliability* of the adopted IT artifact (e.g., Dixon et al., 2013) generates consistent negative empirical results in CC and ITO adoption contexts, although it is examined fewer than five times.

Table 2 Determinant factors for cloud computing adoption decision in healthcare

Determinant factors along five categories	**Relationships from single conceptual view**		
	Cloud computing	IT outsourcing	IT innovation
Technology			
● Improvement of quality of care (++) ◄	{(++); (<5)}	{(++); (<5)}	{(++); (≥5)}
● Improvement of finances (++)	(incon.); (<5)	{(++); (<5)}	{(+); (<5)}
○ Compliance with standards (++)◄	{(++); (<5)}	{(++); (<5)}	{(++); (<5)}
○ Ongoing costs (--)	{(--); (<5)}	(unclear)	{(--); (<5)}
○ Reliability (--)	{(--); (<5)}	(unclear)	{(--); (<5)}
○ Setup costs (--)	{(--); (<5)}	(unclear)	{(--); (<5)}
Organization			
● For-profit status (++)◄	(unclear)	{(++); (<5)}	{(+); (≥5)}
● IT culture (++)	(unclear)	{(++); (<5)}	{(++); (<5)}
<u>Resources</u>			
● Financial resources (++)	{(++); (<5)}	{(+); (≥5)}	{(++); (<5)}
● IT budget (++)	{(++); (<5)}	{(++); (<5)}	{(++); (<5)}
● IT capabilities (+)	(incon.); (<5)	{(+); (<5)}	{(++); (≥5)}
● IT sophistication (+)	{(++); (<5)}	{(++); (≥5)}	{(+); (≥5)}
○ IT staff (++)	{(++); (<5)}	{(++); (<5)}	(--); (<5)
Environment			
● Industry standards (++)	{(++); (<5)}	(unclear)	{(++); (≥5)}
● Market maturity (++)	(unclear)	{(++); (<5)}	{(+); (<5)}
● IT artifact penetration (+)	(unclear)	{(++); (<5)}	{(+); (≥5)}
● Related references (++)◄	{(++); (<5)}	(unclear)	{(++); (≥5)}
○ Competitive pressure (++)	{(++); (<5)}	(incon.); (≥5)	{(++); (<5)}
<u>Resources</u>			
● Special funding (+)◄	{(++); (<5)}	{(++); (<5)}	{(+); (≥5)}
Data/Information			
● Data interoperability (--)◄	{(--); (<5)}	{(--); (<5)}	{(-); (<5)}
● Privacy (--)◄	{(--); (<5)}	{(--); (<5)}	{(-); (<5)}
○ Security (--)◄	{(--); (<5)}	{(--); (<5)}	(incon.); (≥5)
Stakeholders			
<u>Administrator</u>			
● Top management support (+)	{(++); (<5)}	{(++); (<5)}	{(+); (≥5)}
<u>Patient</u>			
○ Patient preference (++)◄	(unclear)	{(++); (<5)}	{(++); (<5)}
<u>Policy maker</u>			
● Central push (++)	{(++); (<5)}	{(++); (<5)}	{(+); (≥5)}
● Mandate (MM) ◄	{(M); (<5)}	{(MM); (<5)}	{(MM); (≥5)}
<u>Physician</u>			
● Physician support (++)◄	(unclear)	{(++); (<5)}	{(++); (≥5)}
○ Involvement in administration (++)◄	(unclear)	{(++); (<5)}	{(++); (<5)}
<u>Vendor</u>			
● Vendor competence (++)	{(++); (<5)}	{(++); (<5)}	{(+); (<5)}
● Vendor support (+)	{(++); (<5)}	(unclear)	{(+); (≥5)}
○ Business interdependency (M) ◄	(unclear)	{(MM); (<5)}	{(MM); (<5)}
○ Physical distance (--)	{(--); (<5)}	(unclear)	{(--); (<5)}

Legend.
●/○: The determinant factor is reliable/potential. Its evidence is consistent in at least two conceptual views and has been examined more than five times in total/but has not been tested more than five times in total
◄: industry-specific determinant factor for healthcare
(++)/(--): More than 80% of the evidence is positively/negatively significant
(+)/(-): Between 60% and 80% of the evidence is positively/negatively significant
(unclear)/(incon.): Evidence is not tested/inconsistent for the conceptual view
(MM)/(M): More than 80%/Between 60% and 80% of the evidence is significant but non-directional
(≥5)/(<5): Factor is examined more/less than five times for the conceptual view
{ }: Evidence for the conceptual view is included to determine the total effect of the factor

Ongoing costs (e.g., Yoon, Chang, Kang, Bae, & Park, 2012) and setup *costs* (e.g., Alkraiji, Jackson, & Murray, 2013) are the other two *potential* determinant factors. These factors both deliver a *consistent* negative effect regarding CC and ITI but have been studied fewer than five times.

Category: *organization*. The *organization* category includes the attributes and status of a healthcare organization that adopts CC. This category contains 34 *master variables* that have been studied a total of 167 times. It must be emphasized that 13 of the 34 master variables are related to the healthcare organization's internal resources for IT adoption (studied 68 times; see Table A.2). In this category, the *size* of the healthcare organization has been most frequently studied (25 times; cf. Table A.2).

Six *reliable* determinant factors have been identified for this category. *IT culture* measures a healthcare organization's tradition of using or (traditional) tendency to use innovative IT artifacts (e.g., Mills et al., 2010), whereas *for-profit status* indicates the degree to which the healthcare organization is driven by a profit motive (e.g., Hill, 2000). Both determinant factors are identified as having *consistent* and *robust* positive effects with respect to ITO and ITI. The four remaining *reliable* determinant factors relate to an organization's internal resources for IT adoption. Among them, (general) *financial resources* (e.g., Cao, Baker, Wetherbe, & Gu, 2012), *IT budget* (of the healthcare organization; e.g., Baker et al., 2008), and *IT sophistication* (in terms of IT infrastructure or the general use of IT in the healthcare organization; e.g., Lai, Lin, & Tseng, 2014) are considered *reliable* from the CC, ITI and ITO perspectives. Healthcare organizations' *IT capabilities* (e.g., Wholey, Padman, Hamer, & Schwartz, 2001) are shown to have a *consistent* positive effect on IT adoption when ITO and ITI are considered. Availability of *IT staff* (e.g., Yoon et al., 2012), the only *potential* determinant factor in this category, has a positive effect if we consider CC and ITO studies.

Category: *environment*. The environment category describes the characteristics and status of the surroundings, context or industry in which the healthcare organization operates. In this category, 12 *master variables* have been studied a total of 74 times. As shown in Table A.2, the two most frequently examined master variables are *competitive pressure* (17 times) and the *ruralness* of the location of the healthcare organization (13 times). Two *master variables* (i.e., *industrial IT infrastructure* (3 times) and *special funding* (8 times)) that address healthcare organizations' external resources for IT adoption are also included in the *environment* category.

Industry standards (e.g., Yoon et al., 2012), *related references* (e.g., Baird, Furukawa, & Raghu, 2012), *market maturity* (for the adopted IT artifact; e.g., Bodker, 2002), *IT artifact* *penetration* (i.e., popularity of the adopted IT artifact in the industry; e.g., Potančok & Voříšek, 2015), and *special funding* (from the industry for the adoption of the IT artifact; e.g., Nielsen & Mengiste, 2014) are *reliable* determinant factors in this category. The first two of these determinant factors have a consistent positive effect on CC and ITI, whereas the third and fourth factors have a consistent positive effect on ITO and ITI. The fifth determinant factor, *special funding,* is considered *reliable* for CC, ITI and ITO. *Competitive pressure* (e.g., Li, Chang, Hung, & Fu, 2005) in the healthcare industry is the only *potential* determinant factor in this category. For CC and ITI, this factor has a *consistent* positive effect but is not proven to be *robust*. Although this determinant factor has been studied more than five times from an ITO perspective, no *consistent* result is observed.

Category: *data/information*. This category refers to the use of data or information, or the data/information-related considerations of the healthcare organization. Data are structured facts and/or statistics, whereas information focuses on unstructured messages or human thoughts. The three most-studied master variables—*security* (ten times), *privacy* (seven times) and *data interoperability* (five times)—also serve as *reliable* or *potential* determinant factors. *Data interoperability* (e.g., Dixon et al., 2013) refers to concerns about data to be smoothly exchanged or integrated as required with different (internal or external) sources. This determinant factor possesses a *consistent* negative effect across all CC, ITO and ITI contexts that is *robust*. Therefore, this factor is a *reliable* determinant factor in this category. Another *reliable* determinant factor with a negative effect that also relates to the CC, ITO and ITI contexts is (concerns about information and data) *privacy* (e.g., Simon et al., 2007). The determinant factor of *security* (e.g., Sultan, 2014a) represents healthcare organizations' information and data security concerns. Although *security's* empirical results are *consistent* from the CC and ITO viewpoints, the effect in ITI studies is shown to be inconsistent, which prevents this determinant factor from achieving high *robustness*. Thus, *security* is a *potential* determinant factor.

Category: *stakeholders*. The last category covers stakeholders' characteristics, attitudes and behaviors that are related to the adoption of the IT artifact by the healthcare organization. For this category, 46 *master variables* are identified and have been studied 131 times. As shown in Table S.2, these *master variables* are distributed in six stakeholder groups: *administrator* (of the healthcare organization), *patient*, (industry) *policy maker*, *physician* (of the healthcare organization), (IT/IT service) *vendor*, and IT *user*.

The most-studied *master variable* in *administrator* is *top management support* (15 times; e.g., Lian et al., 2014), which is the only *reliable* determinant factor with a *consistent* positive effect in this stakeholder group. In the stakeholder group *patient*, the most-examined *master* *variable* (i.e., (number of) *insured patients*) has been studied only three times (cf. Table A.2). Thus, no *reliable* determinant factors can be found. However, *patient preference* (for the adoption of the IT artifact; e.g., Khoumbati, Themistocleous, & Irani, 2006) possesses consistent positive empirical results from the ITO and ITI views and acts as a *potential* determinant factor. The stakeholder group *policy maker* contains two *master variables* (i.e., *central push* and *mandate*), which are both *reliable* determinant factors with respect to all three perspectives. *Central push* refers to the specific activities of the policy maker that support, promote or mandate the application of the IT artifact (e.g., Lin, Lin, Roan, & Yeh, 2012; Mills et al., 2010; Potančok & Voříšek, 2015). This determinant factor has a positive effect on the adoption of the IT artifact. The other *reliable* determinant factor is the availability of policies that specify the policy maker's mandate regarding the use (or non-use) of the IT artifact (e.g., Spinardi, Graham, & Williams, 1997). This determinant factor is revealed to have a consistent *significant* effect, but no direction. In the stakeholder group *physician*, *physician support* (e.g., Paré & Trudel, 2007) is the only *reliable* determinant factor with a consistent positive effect. Although the degree of physicians' *involvement in administration* (e.g., Yang, Kankanhalli, Ng, & Lim, 2013) also has consistent positive empirical results, it has been examined fewer than five times. The consistent positive effects of both determinant factors relate to ITO and ITI. In the stakeholder group *vendor*, the two most-examined *master variables*, namely, *vendor support* (14 times) and *vendor competence* (8 times) are also the only two *reliable* determinant factors of *vendors*. Whereas *vendor competence* (e.g., Marsan & Paré, 2013) has a consistent positive effect regarding CC, ITO and ITI, *vendor support* (e.g., Li et al., 2005) has not been examined in the ITO context, and its positive effect is thus consistent from the CC and ITI perspectives. Moreover, two *master variables* play the role of *potential* determinant factors for *vendor*. *Business interdependency* (e.g., Yang et al., 2013), which denotes the degree to which the IT vendor is strategically related to or allied with the healthcare organization, has been shown to deliver *consistent* but not-robust empirical results regarding ITO and ITI. A vendor's *physical distance* from the healthcare organization, indicating a *consistent* negative effect with respect to CC and ITO, is the other *potential* determinant factor. Although we identified a further stakeholder group *user*, which contains four *master variables* that have been studied six times, no *reliable* or *potential determinant* factors can be derived for this stakeholder group.

4.4. Industry-Specific Variables of Cloud Computing Adoption in Healthcare

As described in section 2.3, Schneider & Sunyaev (2016) and Jeyaraj et al. (2006) have delivered comprehensive lists of determinant factors for the adoption of IT in the context of

CC, ITI and ITO. By reflecting on our research and comparing our results with those of Schneider & Sunyaev (2016) and Jeyaraj et al. (2006), we identified 47 *master variables* that are specific for the adoption of CC/ITO/ITI in the healthcare industry. These industry-specific variables have not been addressed in general or other industry contexts. In particular, these variables reflect specific characteristics of the healthcare industry that have been stressed by the reviewed literature. We highlight these industry-specific *master variables* in Table S.2 and describe their specificities. These *master variables* are further discussed in section 5.

5. Discussion

5.1. Specificities of Cloud Computing Adoption in Healthcare

By observing the identified *master variables*, we identified industry specificities of CC adoption in healthcare, which are reflected from two perspectives. On the one hand, the identified *master variables* that also exist in general contexts show different empirical results in the healthcare industry, reflecting the specific situation of CC adoption in the context of healthcare, as discussed below. On the other hand, the industry-specific *master variables* profile the unique aspects of the healthcare industry that must be considered for CC adoption. More specifically, we use induction to generalize from the identified industry-specific *master variables* and propose two special characteristics of the healthcare industry that should be considered for CC adoption. It is stressed that we employed a focus group discussion with seven external researchers from IS or MI to validate both derived characteristics in September 2017. The first characteristic of these variables is summarized as the *medical and clinical role* of the healthcare industry. The *medical and clinical role* is defined as medical/clinical specific considerations or characteristics that are also related to the use of IT (DesRoches & Rosenbaum, 2010; Mandl & Kohane, 2012). The healthcare industry is particularly differentiated from other industries by the high professionalism of its core business, providing care services. Highly specific and complex medical and clinical processes in different healthcare organizations and their different roles in the supply chain of health-related services have an impact on IT activities (Chiasson & Davidson, 2004). Moreover, the uniqueness of health IT (e.g., CC in healthcare) is, in essence, its utility for medical and clinical activities in healthcare organizations and thus improved quality of care (Mandl & Kohane, 2012; Sultan, 2014b). The second characteristic is defined as the *public role*. Although the healthcare industry is by no means a pure public sector, it carries the characteristics of the public sector to a certain extent for the following two reasons. First, a large portion of the products and outcome of the healthcare industry are public goods, which benefit and are available to all, at least locally and temporarily (Hemenway, 2010). These public goods are, for example, the prevention or treatment of fatal communicable disease, vaccination against preventable childhood diseases, and emergency medical interventions (Leaning & Guha-Sapir, 2013). Thus, healthcare organizations' success does not necessarily depend on profitability but also (or more) on social values such as public health. Healthcare organizations voluntarily assume social responsibilities and contribute to the public, with occasional sacrifices. Second, a high level of governmental intervention is present in the healthcare industry. Compared with other industries (e.g., financial services), governments do not only strictly regulate healthcare organizations but are also deeply involved in mandating and financing private healthcare organizations' activities and even provide healthcare services directly (Hanson et al., 2008; Hemenway, 2010). According to a recent study, 66.5% of global healthcare expenditures are financed by governments (Dieleman et al., 2016); all major countries have publicly owned entities for providing healthcare services (Mossialos, Wenzl, Osborn, & Sarnak, 2016). The identified industry-specific *master variables* are described/explained by using the *medical and clinical role* and *public role* in Table S.2 and will be discussed further below.

The identified *master variables* in the *technology* category correspond to the traditional technological perspective of IT adoption studies. In particular, typical factors such as *compatibility* or *complexity* have been closely examined in the healthcare context (cf. Table A.2). However, these typical factors do not show consistent empirical results for the healthcare context, although they have been proven to be suitable predictors for general CC, ITO and/or ITI adoption studies in IS (Jeyaraj et al., 2006; Schneider & Sunyaev, 2016). The only two *reliable* determinant factors—*improvement of quality of care* and *improvement of finances*—indicate that healthcare organizations are likely to concentrate on direct, specific benefits that can be caused by CC adoption rather than the traditional technical characteristics that are suggested by the DOI theory. The potential for the *improvement of quality of care* can positively influence the adoption of CC, particularly because care-related service is a healthcare organization's core business. In contrast to traditional health IT applications, CCSs show promise in supporting clinical activities (cf. Griebel et al., 2015). Our literature review shows that the direct improvement of health-related services by the adopted IT artifact has therefore become one of the key adoption motivations of healthcare organizations (e.g., England & Stewart, 2007; Lorence & Spink, 2004). Another *reliable* determinant factor (i.e., *improvement of finances*) holds for CC adoption in healthcare contexts because financial benefits have been argued to be the "principle advantage" (p.5) of CC in healthcare (Kuo, 2011). Other *master variables*, such as *ongoing costs*, setup *costs*, and *transaction costs* also reflect healthcare organizations' financial considerations for CC adoption. The *category technology* contains two industry-specific *master variables* (i.e., *improvement of quality of care* and *compliance with standards*). Whereas *improvement of quality of care* reflects clinical/medical considerations and thus the *medical and clinical role* of the healthcare industry, *compliance with standards* represents the *public role*. CC adoption studies in general contexts merely concentrate on the existence of industry standards for CCSs (cf. Schneider & Sunyaev, 2016). Our study reveals that healthcare organizations additionally regard the degree to which CCSs adhere to related industry standards (i.e., *compliance with standards*), as an important precondition for the adoption decision (e.g., Alkraiji et al., 2013; Raube, 2015). This finding stems from the strict government regulation (or occasionally behavioral mandates) over the use of health IT (Baird et al., 2012), which could directly influence public health or have other social impacts (e.g., pertaining to the privacy of personal health data). Thus, *compliance with standards* has become an industry-specific measurement of the quality of CCSs in healthcare.

We observe that the *reliable* and *potential determinant* factors in the second category mainly originate from master variables that relate to *resources*. Although the other master variables (i.e., those that are not related to resources) have been examined extensively (21 master variables examined a total of 99 times), only two *reliable* dominant factors can be found. This finding likely stems from the fact that many *master variables* that are valid in general IT adoption contexts do not necessarily play a role in the healthcare context (e.g., *size* or *organizational centralization*). This observation is likely caused by the high complexity of a healthcare organization and the fact that a single factor regarding *organization* is sometimes insufficient to influence CC adoption. The *organization* category has a high proportion of industry-specific *master variables*. The most frequently examined industry-specific *master variable* (i.e., *for-profit status*) is actually one of two *reliable* determinant factors that have a positive effect on CC adoption because for-profit healthcare organizations are more likely to have the financial flexibility to engage in adoption activities (e.g., Burke, Wang, Wan, & Diana, 2002). In the *organization* category, the industry-specific *master variables* have been underestimated; on average, they have been studied less frequently than the general *master variables* (3 vs. 5.95 times). Moreover, many significant *industry-specific* master variables have been discussed only within a single context (CC, ITO, or ITI), although they can arguably play a role in other contexts. For example, *teaching status* has a positive effect on the adoption of ITO because *healthcare organizations* with teaching responsibilities receive additional funding (e.g., from medical schools), which can be used for IT adoption (Kazley & Ozcan, 2007). Moreover, healthcare organizations with *teaching status* contribute to medical research, which relies heavily on the processing of large quantities of data. Because the adoption of CC and ITO also requires substantial financial resources and CC can offer scalable computing resources for data processing (cf. Table A.1), the *teaching status* of healthcare organizations can also facilitate CC adoption.

There are various types of master variables in the second category that represent healthcare organizations' resources, among which only monetary (e.g., *IT budget*) and IT-specific resources (e.g., *IT capabilities*) serve as *reliable* and *potential* determinant factors. This finding reveals the importance of both kinds of resources. Monetary resources refer to healthcare organizations' budgets or spending, which can be directly or indirectly available for IT adoption projects. IT-specific resources comprise the IT capabilities, IT staff and IT infrastructure of a healthcare organization. Our study shows that monetary and IT-specific resources have a positive impact on CC adoption in healthcare organizations. Previous research demonstrates that CC adoption does not require a high degree of financial and IT input in general contexts; this is one of CC's major benefits for users (Marston et al., 2011). However, our review shows that these findings do not hold in healthcare. Rather, we found that due to the high heterogeneity of healthcare organizations, standard CCSs are often not ready to use and require additional implementation or configuration steps (Sultan, 2014a). Because the IT infrastructure in healthcare organizations is often lagging, additional work to upgrade hardware (e.g., Internet connections) or platforms becomes necessary (Weng et al., 2016). Furthermore, CC projects in healthcare are often large in scale and require the involvement of multiple organizations, including governments (in contrast, CC projects in other industries often involve a single small or mid-sized enterprise) (Lian et al., 2014), thus entailing the additional effort and expense of coordination (Kipp, Riemer, & Wiemann, 2008). Accordingly, healthcare organizations often need significant IT-specific and/or monetary resources for CC adoption.

The industry-specific *master variables* in the second category can also be explained by the *medical and clinical* aspects and *public role* of the healthcare industry. Whereas *master variables* such as *clinical needs* and *focus on chronic care* represent medical/clinical considerations, *master variables* such as *intention for social gain* and *for-profit status* reflect the *public role*.

The third category, *environment*, contains twelve *master variables*. One-half of the identified *master variables* deliver consistent empirical results and serve as *reliable* (n=5) or *potential* (n=1) determinant factors in CC adoption. Notably, many of these determinant factors (4 of 6) exist in common contexts of CC adoption studies, which have not delivered consistent empirical results (cf. Schneider & Sunyaev, 2016). This finding is likely due to the high consistency of the *environment* (i.e., the healthcare industry) in the studies reviewed in our research, as previously argued by Schneider & Sunyaev (2016).

The only two *master variables* in this category that are industry-specific and regarded as *reliable* determinant factors are *related references* and *special funding*. *Related references* refer to the successful use of CCS by other clients who have profiles (e.g., geographic area, size, clinical focus) that are very similar to the profile of the healthcare organization that is interested in adopting CCS. This determinant factor is relevant for CC adoption in the healthcare industry because a remarkable feature of CCSs is that they are often expected to use standardized software (SaaS) or infrastructures (IaaS/PaaS) that serve a wide variety of customers (Marston et al., 2011). However, healthcare organizations differ substantially from each other. Even minor differences among them in terms of healthcare service focus or specifications leads to very different clinical and/or service management processes (Lee, Song, & Kim, 2014). Therefore, one CCS cannot serve all healthcare organizations; rather, it can only serve a few such organizations with similar profiles. The other master variable that serves as a sufficient determinant factor is *special funding* (for CC adoption). This variable represents government and industry financial support that supplements healthcare organizations' internal resources. In contrast to other industries, the monetary resources for CC adoption are often available from government or social sources, reflecting the *public roles* of the healthcare industry that impact CC adoption. Other industry-specific *master variables* in this category also represent the healthcare organization's *public* (e.g., *penetration of health insurance*) and/or *medical and clinical roles* (e.g., *care system maturity*). However, these *master variables* have been under-investigated and thus examination of their empirical results does not deliver sufficient insights.

The *data/information* category serves as another important aspect for CC adoption in healthcare. This category represents *healthcare organizations'* considerations for CC adoption from the data/information perspective. All the *master variables* in this category are industry-specific. Although *data/information* contains *security*, which has also been discussed by CC adoption studies in general contexts (cf. Schneider & Sunyaev, 2016), it has a special focus in healthcare. In contrast to other contexts, in which the definition of *security* is broader and covers IT hardware, software and data (Ramachandran, 2016), the master variable *security* in a healthcare context focuses mainly on concerns about the improper or insufficient protection of data or information from unauthorized use or manipulation (Sultan, 2014a). Similarly, *privacy* concerns, which regard improperly addressing data or information in healthcare and garner minimal focus in general CC or ITI adoption studies (Jeyaraj et al., 2006; Schneider & Sunyaev, 2016), also play an important role in CC adoption in healthcare. Security and privacy issues are deemed CCs' Achilles' heel by a substantial amount of research because data or information in CCSs is often not processed for users on-site (e.g., Jaatun et al., 2016; Sunyaev & Schneider, 2013). Our review shows that healthcare organizations are sensitive to the impact of security and privacy issues that result from CC adoption because healthcare data and information (i.e., from patients) are highly personal, health-related and concern nearly everyone. The leakage or misuse of such data could cause serious loss for a wide range of the public and have a substantial social impact. Moreover, healthcare organizations heavily rely on data/information for clinical decisions and delivering healthcare services (cf. section 5.2). Data manipulation could lead to low-quality care and medical errors. Finally, strict legal regulations force healthcare organizations to assume substantial responsibility to effectively oversee data/information (Choi, Capitan, Krause, & Streeper, 2006). Thus, *security* and *privacy* represent both the *public* and the *medical and clinical roles* of the healthcare industry regarding data/information. The remaining four *master variables—data/information centralization*, *data digitalization*, *data/information processing needs, and data interoperability*—involve the use of or need for data/information in healthcare services, as described by Table S.2. Therefore, these industry-specific *master variables* represent the *medical and clinical role* of the healthcare industry with respect to data/information.

The final category regards *stakeholders* of healthcare organizations. This category addresses different roles that are relevant to healthcare organizations. Jeyaraj et al. (2006) note that, in general contexts, ITI studies insufficiently focus on factors related to individual roles in the organizational adoption of ITI. Schneider & Sunyaev (2016) have also identified a very limited number of factors related to individual roles for CC adoption in general contexts. Our study reveals that the *master variables* of the category *stakeholders* have primarily been studied (132 times) in healthcare contexts. In contrast to Jeyaraj et al. (2006) and Schneider & Sunyaev (2016), we reveal a clear differentiation between different stakeholder groups and each of those groups' unique master variables. These groups do not only cover the stakeholders that also exist in general IT adoption contexts, such as *administrator* or *vendor* (Ali, Warren, & Mathiassen, 2017), but also stakeholders specific to the healthcare industry (e.g., *physician* and *patient*). Industry-specific *master variables* in this category primarily exist in but are by no means limited to industry-specific stakeholder groups. For example, in the stakeholder group *administrator* of healthcare organizations, studies also investigate the *administrator's involvement in medical activities* (Kimberly & Evanisko, 1981). The core business of healthcare organizations (i.e., healthcare services) has a high level of professionalism. Healthcare administrators who are involved in medical activities therefore can better understand their business and medical needs. In practice, it is common for many healthcare organizations to employ physicians or managers with a medical background as administrators. The previous research has also empirically shown that healthcare organizations with such administrators have better performance than those with administrators lacking a medical background (Goodall, 2011). Thus, *administrator's involvement in medical activities* can have a positive impact on CC adoption, particularly because CCSs are expected to directly improve healthcare services. *Administrator's involvement in medical activities* thus represents *the medical and clinical role* of *administrators*. As further examples, we identified industry-specific *master variables* in the stakeholder group *vendor*: *vendor's medical knowledge*, *business interdependency*, and *role multiplicity in healthcare*. Vendors with *medical knowledge* are argued to positively support CC adoption because of the high professionalism of healthcare services (Reddy et al., 2008). *Business interdependency* indicates the degree to which a healthcare organization is strategically related to its IT vendor, and *role multiplicity in healthcare* refers to the additional roles (e.g., care provider) of the IT vendor in healthcare. *Business interdependency* and *role multiplicity in healthcare* refer to a special form of IT sourcing as well as CC sourcing in healthcare (e.g., Glasberg, Hartmann, Draheim, Tamm, & Hessel, 2014; Reddy et al., 2008), in which a healthcare organization serves as the IT provider for its client healthcare organization, particularly because healthcare-related ITO/CC-outsourcing in certain areas is legally restricted to IT providers that are also healthcare organizations (Glasberg et al., 2014). In this special form, the IT client healthcare organization relies not only on IT services by its IT provider but also on the related medical resources and therefore has a high level of business dependency on the IT provider. The IT provider healthcare organization plays another role (i.e., healthcare service provider) in addition to IT provider in the CC adoption. The relationship between client and provider is characterized by both cooperation and competition (Reddy et al., 2008) and could have a significant impact on CC adoption, as demonstrated by our review.

5.2. Conceptual Implications and Recommendations for Future Research

Through our review, we obtained insights into the use of concepts for CC adoption studies in healthcare contexts that provide implications and directions for future research. We summarize those insights by proposing a conceptual model of determinant factors for CC adoption in healthcare contexts, as illustrated in Figure 2.

Based on the results of our review, our conceptual model consists of six categories of variables that influence CC adoption in healthcare organizations: *technology*, *organization*, *environment*, *resources*, *data/information* and *stakeholders*. While the first four categories (dotted boxes in Figure 2) acknowledge the relevance of basic categories in traditional IT adoption theories, the last two categories (solid boxes) reflect the industry-specific

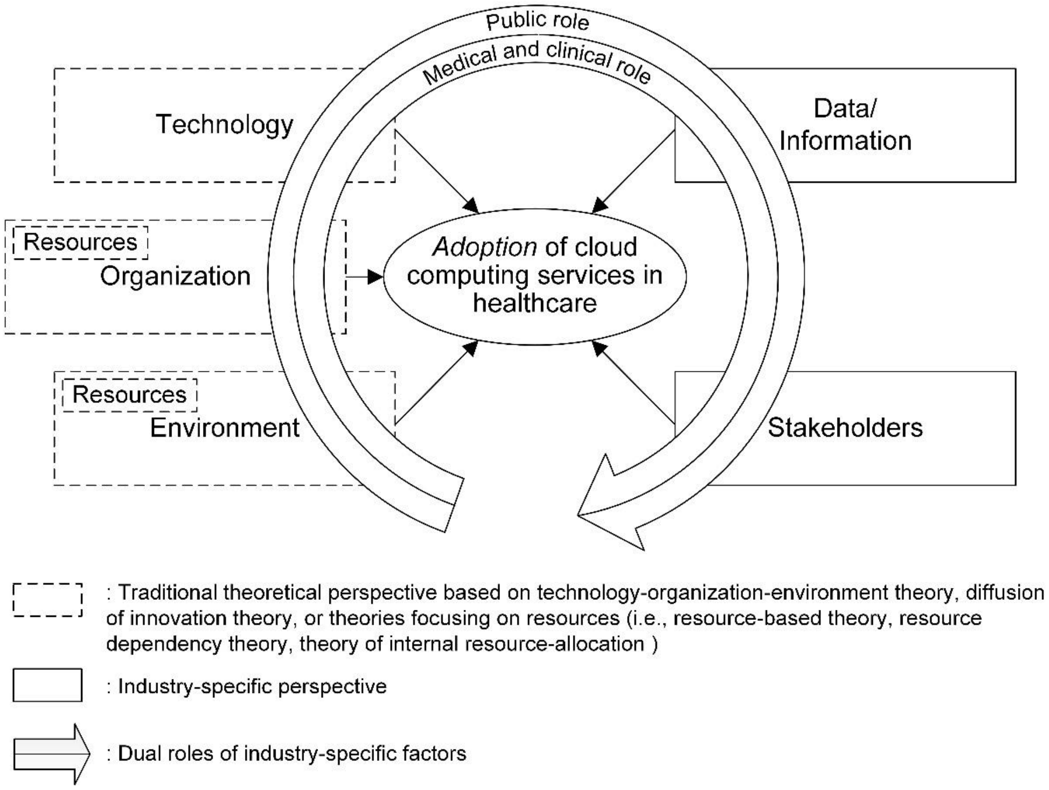

Figure 2 Conceptual model of determinant factors for cloud computing adoption in healthcare contexts

categories of variables that influence CC adoption in healthcare. Moreover, our conceptual model highlights two specific concerns of the healthcare industry that influence CC adoption and are reflected by industry-specific master variables: the *medical and clinical role* and the *public role*. Neither role is restricted to any of the conceptual categories but exists across all of them. We illustrate this observation by drawing a circle across all categories in the conceptual model. Implications of the conceptual model and related recommendations for future research are further discussed below. Table 3 summarizes these recommendations and shows how they are related to our research findings.

The four dotted boxes in the conceptual model reflect the relevance and the eligibility of the TOE theory, the DOI theory, and the theories focusing on resources for CC adoption studies. We therefore recommend that both IS and MI researchers who conduct theory-driven studies on CC adoption in healthcare further adhere to these "good" theories and the four related conceptual categories **(Recommendation 1)**. Particularly as the MI community has begun to recognize the importance of (IS) theories for the healthcare domain (Cockcroft, 2015) and because of the importance of the research topic of CC adoption in healthcare, an increasing number of studies that rely on theories to explore CC adoption in healthcare are expected to appear. Moreover, we suggest that researchers further apply the *master*

Table 3 Recommendations for Future Research

Findings	Related Recommendation for Future Research
Technology, *organization*, *environment*, and *resources* are useful for explaining cloud computing adoption in healthcare	Adhere to IT adoption theories that rely on these four conceptual categories to investigate cloud computing adoption in healthcare
Concrete variables are found to deliver consistent empirical results	Apply identified variables that deliver consistent empirical results as a solid foundation to investigate cloud computing adoption in healthcare
Data/information, which has only been discussed in a unsystematic manner, serves as a relevant conceptual category,	Employ a theoretical lens to data or information (in healthcare) to investigate cloud computing adoption in healthcare
Unlike in general contexts, impacts of individuals on cloud computing adoption in healthcare differ largely based on their roles	Differentiate the impacts of different stakeholder roles on cloud computing adoption in healthcare
Despite the relevance of the identified conceptual category *Stakeholders*, only limited stakeholder roles have been examined	Expand stakeholder roles for their different impacts on cloud computing adoption in healthcare
Concrete industry-specific variables for healthcare have been identified	Focus on identified industry-specific master variables in future cloud computing adoption studies in healthcare
Features of the identified industry-specific variables can be explained and generalized by using *public role* and *medical and clinical role* of healthcare	Rely on *public role* and *medical and clinical role* to find and select further industry-specific variables

variables, which have been found to deliver consistent empirical results, in future studies of CC in healthcare (cf. Table 3) **(Recommendation 2)**. It must be stressed that a few of these *master variables* have not been closely examined and thus act as *potential determinant factors*. However, these variables' consistent empirical results will allow them to provide promising insights into CC adoption in healthcare and to support researchers in related future studies.

Our model proposes two further conceptual categories for CC adoption that reflect the industry specificities of CC adoption in healthcare. The first conceptual category is *data/information*. Previous IT adoption research views data or information either as a subordinate of technology or as an organizational resource (cf., Jeyaraj et al., 2006; Schneider & Sunyaev, 2016). However, both views either restrict or improperly conceptualize the role of information/data for the healthcare industry, according to the following findings. First, in healthcare, data and information are not necessarily products of IT but consumers of IT. In other words, data and information exist and support healthcare organizations, with or without IT. In the U.S., where the use of health IT has been strongly advocated, paper-based working processes to collect and address data or information remain common (Badalucco, 2015). Our review reveals that in many healthcare situations, data and information management tools that are not IT-related are sometimes reported to be more effective and/or efficient for healthcare providers and patients (Baird et al., 2012;

Mouttham, Kuziemsky, Langayan, Peyton, & Pereira, 2012). Thus, researchers begin to make data and information the focus and examine how IT can orient itself to data and information in healthcare (rather than the other way around) (Lim et al., 2018; Pirnejad, Niazkhani, van der Sijs, Berg, & Bal, 2009; Unertl, Weinger, Johnson, & Lorenzi, 2009). Second, data and information do not (only) mean resources to healthcare organizations. In the context of IT adoption, resources are understood as stocks of available factors (e.g., assets and capabilities) that are owned and controlled by the organization and that enable the organization to achieve competitive advantages and/or improve efficiency and effectiveness (Daft, 2007). It is true that healthcare organizations collect information and data, which mainly originate from patients, to deliver healthcare services. These healthcare organizations do not necessarily own the information and data as their property, and their use should be controlled by patients (Haug, 2017; Mandl & Kohane, 2016). Healthcare organizations conduct research or analysis by collecting patient data, from which knowledge is produced (Sultan, 2014b). However, these data and the knowledge produced thereby are largely treated as “public goods” (p. 648) instead of as individual property (Chestnov, Riley, & Bettcher, 2016). As shown by our studies, master variables related to data/information do not identify them as resources for healthcare organizations that provide competitive advantages. In contrast, concerns related to data/information, including *privacy*, *security*, and *data interoperability*, can lead to issues and thus disadvantages for healthcare organizations. The *data/information* category could play an important role, particularly for the adoption of CC in healthcare, because CC is closely related to data and information. On the one hand, CCSs are web-based by nature and are only enabled by the frequent exchange of data or information between different parties (Dwivedi & Mustafee, 2010; Sultan, 2014b). On the other hand, unique features such as *broad network access*, *resource pooling* and *rapid elasticity* (cf. Table A.1) allow CCSs to effectively support the data/information life cycle in healthcare from data and information collection to processing to archiving (Kuo, 2011). Our review reveals that although certain studies previously began to examine CC adoption by considering data/information, these studies are fragmented and remain in the minority. For future research, we suggest researchers deepen their understanding of the role of data and information for CC adoption in healthcare. In particular, we suggest that future research investigate CC adoption in healthcare by relying on a specific theoretical lens on data or information in healthcare **(Recommendation 3)**. Organizational theories that consider information or data can provide a suitable foundation. Examples of such theories include *organizational information processing theory*, which focuses on organizational information processing needs, information processing capability, and the fit between the two to obtain optimal performance (Galbraith, 1974).

The other category that cannot be sufficiently supported by the applied theories of the reviewed studies is *stakeholders*. Although previous research has stressed the need to seriously consider different stakeholders in the use of health IT (Leidner et al., 2010; Standing & Standing, 2008), the reviewed studies examine the roles of different stakeholders in an unsystematic manner. Although several reviewed studies also use theories that discuss the impact of individual roles, these theories do not sufficiently explain the highly complex situation created by the heterogeneous stakeholders in healthcare. The human, organization and technology-fit (HOT-fit) model of Yusof, Kuljis, Papazafeiropoulou, & Stergioulas (2008) is such a theory and has been employed by three studies (Alam, Masum, Abdul Kadar Muhammad, Beh, & Hong, 2016; Alharbi, Atkins, & Stanier, 2016; Lian et al., 2014). The HOT-fit model stresses the importance of *human*, *organization*, and *technology* perspectives and the degree of *fit* among them for the use of health IT. Although the *human* perspective is related to the *stakeholder* idea, it focuses heavily on the attributes of *users* in health IT. Interestingly, *user* is the only stakeholder group in our review that delivers no *master variable* with consistent empirical results for CC adoption in healthcare. The adoption and use of IT in healthcare includes a large number of stakeholders (Mantzana, Themistocleous, Irani, & Morabito, 2007). The *user* group can have different types of roles in healthcare (e.g., physicians, nurses, patients, administrators, and insurers) with different attributes, attitudes, interests, and behaviors. Therefore, it is not surprising that *master variables* from the *user* stakeholder group cannot deliver meaningful empirical results for CC adoption in healthcare. Whereas Schneider & Sunyaev (2016) and Jeyaraj et al. (2006) propose focusing on general individual factors for CC and ITI adoption in general contexts, we suggest future research on CC adoption in healthcare to systematically examine the impact of different stakeholder roles **(Recommendation 4)**. We recommend the use of seminal work that focuses on the importance of different stakeholder roles in organizations as the theoretical foundation, such as *stakeholder theory*, which discusses the interests and power of different stakeholders for organizational processes (Donaldson & Preston, 1995). Moreover, our review reveals that only a limited number of stakeholder groups (n=6) have been addressed by the current research. Further relevant stakeholder groups who are deemed relevant to health IT adoption (e.g., Mantzana et al., 2007), including but not limited to nurses, insurers, legal professionals and medical researchers, remain untouched. We suggest that future research further expand the stakeholder groups and investigate their impact on CC adoption in healthcare **(Recommendation 5)**. Previous studies (e.g., Mantzana et al., 2007; Nielsen, Mathiassen, & Newell, 2014; Pouloudi & Whitley, 1997) that focus on heterogeneous stakeholders in healthcare contexts could serve as a starting point.

We identified specific *master variables* for CC adoption that only exist in the healthcare industry. Although we found that a few of these variables can deliver consistent empirical results (cf. Table 2), most industry-specific master variables have been under-investigated. For example, a healthcare organization's *focus on chronic care* and a *vendor's medical knowledge* have a positive impact on ITI and ITO adoption, respectively (cf. Table A.2). Both *master variables* have only been studied once, and the review of their empirical results cannot lead to meaningful conclusions about their impact on CC adoption in healthcare. We recommend that researchers conduct in-depth investigations of the industry-specific master variables enumerated by our review **(Recommendation 6)**; these *master variables* represent the specificities of the healthcare industry and thus support researchers' understanding of the uniqueness of CC adoption in healthcare.

The identified industry-specific master variables reflect two specific concerns of the healthcare industry: *medical and clinical role* and *public role*. The previous research primarily restricts medicine-related considerations in health IT adoption to the attitudes and behavior of physicians or medical workers (e.g., Ammenwerth, Iller, & Mahler, 2006; Hu, Chau, Sheng, & Tam, 1999). With respect to the *public role*, existing studies strictly limit their understanding to the impact of policy makers in the healthcare industry (e.g., Blumenthal, 2009; Tang, Ash, Bates, Overhage, & Sands, 2006). We find that the identified industry-specific *master variables*, which are explained by both roles, are not restricted to any of the conceptual categories but exist across all of them (cf. Figure 2). This finding teaches us that the industrial specificities of CC adoption in healthcare should be considered, regardless of which theoretical views and related conceptual categories, according to our review, are considered. Therefore, we recommend that future research always seriously consider the specificities of the healthcare industry and further identify industry-specific factors for CC adoption in healthcare; the *public role* and the *medical and clinical role* could serve as two basic criteria for the identification of such factors **(Recommendation 7)**. It is stressed that, regarding *public role*, future research can employ determinant factors that influence CC adoption (and also more general IT adoption) in the public sector as starting point and investigate their role in the healthcare industry (e.g., Dwivedi, Weerakkody, & Janssen, 2012; Lian, 2015), especially as more CC adoption studies are expected to appear in the public sector (Dwivedi & Mustafee, 2010).

5.3. Contributions

This research contributes to both research and practice. With respect to research, we deliver a comprehensive list of master variables that can be applied to CC adoption in healthcare by future research studies. In contrast to previous related studies (e.g., Schneider & Sunyaev, 2016), our study especially proposes master variables that are specific to the healthcare industry. Our research serves as a response to the calls for research both to improve the understanding of the CC phenomenon in the healthcare industry by Weigel et al. (2013) and to investigate specific factors for a certain context (i.e., the healthcare industry) by Schneider & Sunyaev (2016). More importantly, we propose a conceptual model to explain the use of determinant factors for CC adoption in healthcare and to provide specific recommendations for future research. By applying the concepts of *public role* and *medical and clinical role*, our conceptual model generalizes both characteristics of industry-specific determinant factors for CC adoption and thereby advances our understanding of the related industry specificities in healthcare. The conceptual model and the proposed recommendations serve as a cornerstone for theory development with respect to a relevant IS phenomenon (i.e., CC adoption) in healthcare, which has been advocated by the IS community (Chiasson & Davidson, 2004). Because CC is observed as possessing both ITO and ITI features, we especially argue that knowledge from the conceptual model can also be transferred to ITO and/or ITI adoption in healthcare contexts, which should be further validated by future research.

For practitioners, our list of independent variables can support CC adoption projects in healthcare organizations. Specifically, the master variables with consistent empirical results (Table 2) should serve as a checklist of enablers and barriers, by which practitioners could focus their CC adoption projects.

5.4. Limitations

This research has certain limitations. First, our literature review mainly focuses on studies in research outlets (i.e., journals and proceedings) that are characterized by high quality and a strong reputation. It is by no means assured that all existing related studies have been addressed in our research. However, these journals and proceedings exclude "noise" and thus ensure a high quality of the literature review result (Webster & Watson, 2002). Moreover, we conducted a forward and backward search, as suggested by to supplement the pre-defined research outlets (Vom Brocke et al., 2015; Webster & Watson, 2002). Second, we only reviewed research studies from IS and MI. The topic of health IT is by nature multidisciplinary and involves additional areas such as medicine, management, economics, or law. We focus on IS and MI because, to the best of our knowledge, the topic of CC adoption in healthcare has been the most systematically discussed by both areas. However, we continue to recommend that future research explore this topic in other research domains.

6. Conclusion

The phenomenon of CC in healthcare remains in its infancy, and calls for research on this phenomenon have emerged in both the IS and MI fields (e.g., Kuo, 2011; Weigel, Hazen, Cegielski, & Hall, 2014). CC adoption is one of the most relevant topics for CC in healthcare because of the existing lagging adoption and the industrial specificities that influence the adoption process. We believe that both IS and MI will focus more on this challenging topic in future research, for which our review’s identified master variables, derived conceptual model, and proposed recommendations can serve as a solid foundation.

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Appendices

Table A.1 Unique technical features of cloud computing (Mell & Grance, 2011) and their major value for traditional health IT approaches

Technical feature	Description/Definition	Major value for traditional health IT approaches
On-demand self-service	A cloud user can provide or adjust IT services based on own demand without requiring human interaction with each service provider	To increase healthcare organizations' speed and flexibility in providing unforeseen IT services or resources for emergency events, despite the shortage of skilled IT staff in (rural) healthcare organizations (e.g., Yao et al., 2014)
Broad network access	IT services are available over the network and accessed by diverse client platforms (e.g., PCs; mobile phones; workstations)	To ensure healthcare organizations' ability to gain off-site access to medical data and IT resources (e.g., Reddy & Bhatnagar, 2014)
Resource pooling	The cloud provider's computing resources are pooled and can be dynamically assigned to serve a cloud user according to his demand	To increase IT resources and thus overcome a scarcity of computing and storage capacities that threaten health IT operations (e.g., Ratnam, Dominic, & Ramayah, 2014)
Rapid elasticity	Capabilities can be elastically increased and released, in certain cases automatically, to scale rapidly outward and inward commensurate with demand	To offer timely, dynamic assignment of healthcare organizations' IT resources based on demand and thus to optimize the use of IT resources and avoid IT bottlenecks (e.g., Ratnam et al., 2014; Ahuja, Mani, & Zambrano, 2012)
Measured service	IT services are automatically used, controlled and monitored by leveraging a metering capability (e.g., a pay-per-use mechanism)	To effectively control IT cost (e.g., Kuo, 2011)

Table A.2 Overview of identified master variables and their relationships with adoption of cloud computing/IT outsourcing/IT innovation

Independent variable	***Cloud computing***					***IT outsourcing***					***IT innovation***					∑
	+	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	
Category: technology																
Change of working progress												1			1	1
Compatibility	1		1	1	3						8		3	2	13	16
Complexity				2	2						1	2	3	2	8	10
Compliance with standards	1				1	2				2	1				1	4
Costs		2			2				1	1		2	2	2	6	9
Customization				1	1	1				1						2
Improvement of finances	1			1	2	4				4	2		1		3	9
Improvement of quality of care	1				1	2				2	5				5	8
IT production costs			1		1											1
Loss of productivity												1			1	1
Monitoring potential	1				1											1
Observability											2		1		3	3
Ongoing costs		1			1							2			2	3
Performance expectations							1			1						1
Relative advantages	1			1	2				1	1	6		3	2	11	14
Reliability		3			3							1			1	4
Responsiveness to IT demands						1				1						1
Return on investment											1	1			2	2
Setup costs		1			1							2			2	3
Shared IT expertise						1				1						1
Specificity						1	1		1	3						3
System quality	1				1											1
Technical barriers												1			1	1
Technical limitations												1			1	1
Transaction costs		1			1				1	1						2
Trialability													1		1	1
∑	7	8	2	6	23	12	2		4	18	26	14	14	8	62	103
Category: organization																
Affiliation						1	1			2	6				6	8
Age							1		1	2	1	1	1		3	5
Clinical needs											1				1	1
Culture of collectivism											1				1	1
Focus on chronic care											1				1	1
For-profit status						1				1	6	2	2		10	11
Formalization													1	1	2	2
Insurance reimbursement	1				1						1		1		2	3

Table A.2 Continued

Independent variable	***Cloud computing***					***IT outsourcing***					***IT innovation***					∑
	+	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	
Intention for social gain											2				2	2
Internal needs											4		2	1	7	7
IT complexity											1	1			2	2
IT culture						1				1	4				4	5
IT formalization						1			1	2						2
Medical specialization									1	1	2				2	3
Occupancy rate													1		1	1
Organizational centralization											2	3	1	1	7	7
Public-owned status							1	1		2						2
Size			1		1	1	1			2	16	3	3		22	25
Staff relationships											1		1		2	2
Strategic importance of IT							1			1	1				1	2
Teaching status											4		3		7	7
Resources																
Commitment											1				1	1
Financial resources	2				2	1				1	7		1	1	9	12
Former experience			1		1	1				1						2
IT capabilities	1		1		2	3	1			4	8			2	10	16
IT budget	1				1	2				2	2				2	5
IT sophistication	1				1	4	1			5	5	1	1	2	9	15
IT staff	1				1		2			2	3				3	6
Knowledge about own business						1				1						1
Medical staff											1	1			2	2
Project team competence											1		1	1	3	3
Presence of champions											1		1		2	2
Slack resources						1				1			1		1	2
Space									1	1						1
∑	7		3		10	18	8	1	4	32	83	13	21	9	125	167
Category: environment																
Care system maturity											1				1	1
Competitive pressure	2				2	1				1	7	1	5	1	14	17
Environmental uncertainty													1		1	1
Penetration of health insurance											1				1	1
Industry standards	1				1						8				8	9
IT artefact penetration						1				1	4		1	1	6	7

Table A.2 Continued

Independent variable	***Cloud computing***					***IT outsourcing***					***IT innovation***					∑
	+	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	
Managed care pressure													1		1	1
Market maturity						1				1	3		1		4	5
Related references	1				1						7				7	8
Ruralness						1	1			2	2	7	2		11	13
Resources																
Industrial IT infrastructure											2		1		3	3
Special funding	1				1	1				1	4		1	1	6	8
∑	5				5	5	1			6	39	8	14	3	63	74
Data/information centralization		1			1											1
Data digitalization							1			1						1
Data/information processing needs											2				2	2
Data interoperability		1			1		1			1		2	1		3	5
Privacy		3			3		1			1		2		1	3	7
Security		3			3		1			1		3	3		6	10
∑		8			8		4			4	2	7	4	1	14	26
Category: stakeholders																
Administrator																
Administrator's committee participation												1			1	1
Administrator's cosmopolitanism											1				1	1
Administrator's educational level											1				1	1
Administrator's involvement in medical activities											1				1	1
Assertiveness of top management													1		1	1
CIO’s innovativeness	1		1		2											2
Existence of IT officer											1	1			2	2
Manager’s education substance													1		1	1
Manager’s innovativeness											1			1	2	2
Manager’s tenure											1				1	1

Table A.2 Continued

Independent variable	***Cloud computing***					***IT outsourcing***					***IT innovation***					Σ
	+	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	
Strategic importance of IT officer											2				2	2
Top management attitude											3				3	3
Top management IT skills											1		1		2	2
Top management support	2				2	2				2	7		3	1	11	15
Patient																
Elderly patients													1		1	1
Insured patients											1	2			3	3
Patient educational level											1	1			2	2
Patient employment rate												1			1	1
Patient income													1		1	1
Patient preference						1				1	1				1	2
Patient sovereignty		1			1											1
Policy maker																
Central push	1				1	2				2	5		1	1	7	10
Regulations			1	3	4				3	3	1			8	9	16
Physician																
Chief of medicine's cosmopolitanism													1		1	1
Chief of medicine's tenure													1		1	1
Involvement in administration						1				1	3				3	4
Physician's innovativeness											1				1	1
Physician's intention for social gains											1				1	1
Physician support						1				1	6				6	7
User																
Satisfaction with existing IT											1				1	1
User involvement													2		2	2
User support													2		2	2
User's willingness to change	1				1											1
Vendor																
Business interdependency									2	2				1	1	3
Physical distance		1			1		1			1						2
Possibility of on-site audit	1				1											1
Role multiplicity in healthcare							1			1						1
Simplicity of the vendor side						1				1						1
Trust			1		1						1				1	2

Table A.2 Continued

Independent variable	***Cloud computing***					***IT outsourcing***					***IT innovation***					∑
	+	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	**+**	**-**	**0**	**M**	**#**	
Uncertainty about contract fulfillment		1			1											1
Uncertainty about vendor lock-in		1			1											1
Uncertainty about vendor's stainability		1	1		2											2
Vendor competence	3				3	1				1	3	1			4	8
Vendor's medical knowledge						1				1						1
Vendor push													1		1	1
Vendor support	2				2						8		3	1	12	14
∑	11	5	4	3	23	10	2	0	5	17	52	7	19	13	91	131

Supplementary Material

Table S.1 Overview of journals and proceedings included by the literature review

Information Systems Journal [Search engine]:
Academy of Management Journal [EBSCOhost]
Academy of Management Review [EBSCOhost]
ACM Computing Surveys [ACM Digital Library]
ACM Transactions on Computation Theory [ACM Digital Library]
ACM Transactions on Computer Systems [ACM Digital Library]
ACM Transactions on Database Systems [ACM Digital Library]
ACM Transactions on Embedded Computing Systems [ACM Digital Library]
ACM Transactions on Information and System Security [ACM Digital Library]
ACM Transactions on Information Systems [ACM Digital Library]
ACM Transactions on Intelligent Systems and Technology [ACM Digital Library]
ACM Transactions on Internet Technology [ACM Digital Library]
ACM Transactions on Management Information Systems [ACM Digital Library]
ACM Transactions on Software Engineering and Methodology [ACM Digital Library]
ACM Transactions on Storage [ACM Digital Library]
ACM Transactions on the Web [ACM Digital Library]
ACM Transactions on Intelligent Systems and Technology [ACM Digital Library]
Administrative Science Quarterly [ACM Digital Library]
AI Magazine [ProQuest]
Artificial Intelligence [ScienceDirect]
California Management Review [EbscoHost]
Communication of the ACM [EbscoHost]
Communication of the AIS [AISeL]
Computers and Operations Research [ScienceDirect]
Decision Sciences [EBSCOHost]
Decision Support Systems [ScienceDirect]
European Journal of Information Systems [ProQuest]
Harvard Business Review [EBSCOHost]
Human-Computer Interaction [EBSCOHost]
Human Relations [ProQuest]
IEEE Computer [IEEEXplore]
IEEE Software [IEEEXplore]
IEEE Transactions on Cloud Computing [IEEEXplore]
IEEE Transactions on Communications [IEEEXplore]
IEEE Transactions on Computers [IEEEXplore]
IEEE Transactions on Dependable and Secure Computing [IEEEXplore]
IEEE Transactions on Engineering Management [IEEEXplore]
IEEE Transactions on Mobile Computing [IEEEXplore]
IEEE Transactions on Multimedia [IEEEXplore]
IEEE Transactions on Networking [IEEEXplore]
IEEE Transactions on Networking and Service Computing [IEEEXplore]
IEEE Transactions on Parallel and Distributed Systems [IEEEXplore]
IEEE Transactions on Professional Communications [IEEEXplore]
IEEE Transactions on Reliability [IEEEXplore]
IEEE Transactions on Services Computing [IEEEXplore]
IEEE Transactions on Software Engineering [IEEEXplore]
IEEE Transactions on Systems, Man and Cybernetics [IEEEXplore]
Information and Management [ScienceDirect]
Information and Organization [ScienceDirect]
Information Society [ESCOHost]
Information Systems [ScienceDirect]
Information Systems Frontiers [ProQuest]
Information Systems Journal [ESCOHost]

Table S.1 Continued

Information Systems Journal [Search engine]:
Information Systems Research [ESCOHost]
Information Technology and People [Emerald]
Informing Science [Journal Website]
International Journal of Electronic Commerce [ESCOHost]
International Journal of Information Management [ScienceDirect]
Journal of Computer and System Sciences [ScienceDirect]
Journal of Database Management [ProQuest]
Journal of End User Computing [ACM Digital Library]
Journal of Global Information Management [ProQuest]
Journal of Global Information Technology Management [ProQuest]
Journal of Information Management [ProQuest]
Journal of Information Technology [ProQuest]
Journal of Management Information Systems [ESCOHost]
Journal of Management Systems [Journal Website]
Journal of Systems Management [ProQuest]
Journal of the ACM [ESCOHost]
Journal of the AIS [AISeL]
Journal on Computing [ESCOHost]
Management Science [ESCOHost]
MIS Quarterly [ESCOHost]
MISQ Discovery [ESCOHost]
Operations Research [ESCOHost]
Organization Science [ESCOHost]
Organization Studies [ESCOHost]
Sloan Management Review [ESCOHost]
The DATABASE for Advances in Information Systems [ACM Digital Library]
The Journal of Strategic Information Systems [ScienceDirect]
Information Systems Conference [Search engine]:
European Conference on Information Systems [AISeL]
Hawaii International Conference on System Sciences [IEEEXplore]
International Conference on Information Systems [AISeL]
Medical Informatics Journal [Search engine]:
Applied clinical informatics [PubMed]
Artificial Intelligence in Medicine [ScienceDirect]
Automedica [ScienceDirect]
BioSystems [ScienceDirect]
BMC Medical Informatics and Decision Making [ESCOHost]
British Journal of Healthcare Computing and Information Management [ESCOHost]
Computer Methods and Programs in Biomedicine [ScienceDirect]
Computerized Medical Imaging and Graphics [ScienceDirect]
Computers in Biology and Medicine [ScienceDirect]
Computers, Informatics, Nursing [Journal Homepage]
Health Data Management [ProQuest]
Health Informatics Journal [Journal Homepage]
Health Informatics Online [PubMed]
IEEE Engineering in Medicine and Biology [IEEEXplore]
IEEE Transactions on Information Technology in Biomedicine [IEEEXplore]
Informatics in Primary Care [Journal Homepage]
Informatics Review [Journal Homepage]
International Journal of Electronic Healthcare [Journal Homepage]
International Journal of Healthcare Technology and Management [Journal Homepage]
International Journal of Medical Informatics [ScienceDirect]

Table S.1 Continued

Information Systems Journal [Search engine]:
International Journal of Technology Assessment in Health Care [ProQuest]
Journal of Biomedical Informatics [ScienceDirect]
Journal of Biomedical Semantics [PubMed]
Journal of Clinical Monitoring and Computing [PubMed]
Journal of Medical Internet Research [PubMed]
Journal of Medical Systems [PubMed]
Journal of Pathology Informatics [PubMed]
Journal of Telemedicine and Telecare [Journal Homepage]
Journal of the American Health Information Management Association [PubMed]
Journal of the American Medical Association [PubMed]
Journal of the American Medical Informatics Association [PubMed]
Linux Medical News [Journal Homepage]
MD Computing [PubMed]
Medical and Biological Engineering and Computing [Journal Homepage]
Medical Computing Today [Journal Homepage]
Medical Decision Making [Journal Homepage]
Medical Engineering and Physics [ScienceDirect]
Medical Informatics and the Internet in Medicine [PubMed]
Methods of Information in Medicine [PubMed]
New England Journal of Medicine [PubMed]
Online Journal of Nursing Informatics [Journal Homepage]
Perspectives in Health Information Management [PubMed]
Studies in Health Technology and Informatics [PubMed]
Telemedicine and e-Health [PubMed]
Medical Informatics Conference [Search engine]:
ACM International Health Informatics Symposium [ACM Digital Library]
American Medical Informatics Association Annual Symposium [PubMed]

Table S.2 Full list of identified master variables and their definitions

Master variable	Industry-specific? *yes*	Industry-specific? *no*	Definition ***[Description of the industry specificity when applied]***
Category: technology			
Change of working progress		√	Degree to which the working process is changed by the use of the IT artifact (Paré & Trudel, 2007)
Compatibility		√	Degree to which the IT artifact is perceived as integrated with the existing IT objects (e.g., Lian, Yen, & Wang, 2014) and consistent with the existing values and needs of the healthcare organization (e.g., Lai, Lin, & Tseng, 2014)
Complexity		√	The extent to which the IT artifact is perceived as technically difficult to adopt and use (Lai et al., 2014) or to understand (Hung, Hung, Tsai, & Jiang, 2010)
Compliance with standards	√		Degree to which the IT artifact adheres to industry standards that are regarded as relevant for it (e.g., Hunter, Krupinski, & Weinstein, 2013) *[high regulatory compliance requirements of the healthcare industry to ensure public interests can be guaranteed or will not be impaired through the use of the IT artifact;* ***public role****]*
Costs		√	The amount that the healthcare organization will spend on the adoption of the health IT artifact, including direct costs and indirect costs (e.g., Khoumbati, Themistocleous, & Irani, 2006)
Customization		√	Possibilities that the IT artifact can be customized to the needs and requirements of the healthcare organization (e.g., Dixon et al., 2013)
Improvement of finances		√	Perceived extent to which the financial results of the healthcare organization can be improved through the use of the IT artifact by increasing revenue (e.g., Harrop, 2001) or reducing costs (Lian et al., 2014)
Improvement of quality of care	√		Perceived degree to which the quality that is directly related to patient care or the medical process in the healthcare organization can be improved (e.g., Lorence & Spink, 2004) *[care service is the core of the healthcare industry and its quality is crucial for the healthcare organization's success;* ***medical and clinical role****]*
IT production costs		√	The costs of the hardware, software, and the IT labor resources needed to maintain internal production in the healthcare organization (e.g., Randeree, Kishore, & Rao, 2005)
Loss of productivity		√	Uncertainty about the possibility of decreased productivity for the healthcare organization by using the IT artifact (Simon et al., 2007)
Monitoring potential		√	Degree to which the provided IT artifact or IT services can be formally reviewed, monitored or audited (Dixon et al., 2013)
Observability		√	The degree to which the impact of an innovation is observable to and can be communicated to others (Rogers, 2003)
Ongoing costs		√	Uncertainty about the costs that result from the maintenance or further use of the IT artifact (Low & Chen, 2012; Yoon, Chang, Kang, Bae, & Park, 2012)
Performance expectations		√	The expected results or expected consequences of the use of IT services by the healthcare organization (Reddy, Purao, & Kelly, 2008)
Relative advantages		√	The non-monetary advantages associated with the adoption of the IT artifact that are not further specified or that are only defined in a generic manner (e.g., Lian et al., 2014)
Reliability		√	Uncertainty about the reliability of the provided IT service, including its promised performance and availability (e.g., Dixon et al., 2013)
Responsiveness to IT demands		√	The perceived responsiveness of the IT artifact to users' IT demands (Bodker, 2002)
Return on investment		√	Uncertainty about the return on investment for the IT artifact by the healthcare organization (e.g., Yoon et al., 2012)

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	***no***	
Setup costs		√	Uncertainty about the costs that are related to the initial adoption or the setup of the IT artifact (e.g., Alkraiji, Jackson, & Murray, 2013)
Shared IT expertise		√	Degree to which the healthcare organization can have access to external IT expertise by using the IT artifact (Reddy et al., 2008)
Specificity		√	Degree to which the to-be-adopted IT artifact is functionally specific for the core business of the healthcare organization (e.g., Lorence & Spink, 2004)
System quality		√	Uncertainty about the overall quality of the IT artifact (Low & Chen, 2012)
Technical barriers		√	Perceived level of existing barriers to the adoption and use of the IT artifact (Cao, Baker, Wetherbe, & Gu, 2012)
Technical limitations		√	Perceived degree of limitations of the IT artifact that could lead to insufficient fulfillment of the demands of the healthcare organization (Simon et al., 2007)
Transaction costs		√	Uncertainty about the costs that are involved in exchanges between the healthcare organization and the IT provider, which may include coordination costs, negotiating costs, or governance costs (e.g., Randeree et al., 2005)
Trialability		√	The degree to which the IT artifact can be tried or tested before its adoption by the healthcare organization (Rogers, 2003)
∑	2	24	
Category: organization			
Affiliation	√		The healthcare organization's participation in a strategic affiliation with other healthcare organizations (e.g., Burke, Wang, Wan, & Diana, 2002) *[Complex medical activities often require collaboration between different healthcare organizations and consequently their affiliation; moreover, healthcare organizations target delivering services by using less medical and public resources through affiliation and sharing;* ***medical and clinical role*** and ***public role****]*
Age		√	Age of the healthcare organization (e.g., Kimberly & Evanisko, 1981)
Clinical needs	√		Needs for the IT artifact triggered by existing medical issues in the healthcare organization (Yang, Kankanhalli, Ng, & Lim, 2013) *[The needs for IT support that are directly related to medical areas;* ***medical and clinical role****]*
Culture of collectivism	√		Culture of the healthcare organization to work toward a pre-defined collective goal (by government) with sacrifices (Peng & Kurnia, 2010) *[Healthcare organizations are obligated to fulfill benefits of the society occasionally with scarification of own benefits;* ***public role****]*
Focus on chronic care	√		Degree of the healthcare organization's medical service focus on chronic diseases (Poon et al., 2006) *[Specification of healthcare organizations/healthcare organization type from medical perspective;* ***medical and clinical role****]*
For-profit status	√		Degree to which the operation of the healthcare organization is profit-driven (e.g., Hill, 2000) *[The purpose of the healthcare organization is not necessarily to generate profits but rather to serve the public;* ***public role****]*
Formalization		√	Degree to which the healthcare organization conducts its daily business in a pre-defined structured manner or adheres to established rules or processes (e.g., Chang, Hwang, Yen, & Lian, 2006)

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	*no*	
Insurance reimbursement	√		Degree to which the general business of the healthcare organization is financed or supported by insurance reimbursements (e.g., Kazley & Ozcan, 2007) *[Degree to which a healthcare organization's operation depends on public resources;* ***public role****]*
Intention for social gain	√		The healthcare organization's intention to gain social benefits (e.g., reputation) in its field by adopting the IT artifact *[Business success of the healthcare organization depends on not only its service quality but also its contributions to and impact on the society;* ***public role****]*
Internal needs		√	The degree to which the healthcare organization has an actual need for the IT artifact to fulfill certain purposes (e.g., Liu, 2011)
IT complexity		√	Degree of complexity that the healthcare organization perceives in generally using IT (e.g., England & Stewart, 2007)
IT culture		√	Degree to which the healthcare organization has a tradition of using (innovating) IT products or services or historically acts as an industry leader in the use of IT (e.g., Mills, Vavroch, Bahensky, & Ward, 2010)
IT formalization		√	Degree to which IT-related activities in the healthcare organization are organized or run in a pre-defined structured manner or adhere to established rules or processes (e.g., Harrop, 2001)
Medical specialization	√		The extent to which the healthcare organization is divided into several different subunits or specifications (e.g., Kimberly & Evanisko, 1981) *[Specification of healthcare organizations/healthcare organization type from medical/clinical perspective;* ***medical and clinical role****]*
Occupancy rate	√		The rate of bed occupancy in the healthcare organization (Hill, 2000) *[Measurement of the use of medical resources;* ***medical and clinical role****]*
Organizational centralization		√	Degree to which decisions are made centrally in the healthcare organization (e.g., Standing & Standing, 2008)
Public-owned status	√		Status of the healthcare organization as a government-based organization that provides primary care to the public (regardless of ability to pay or health insurance status) (e.g., federally qualified hospitals) (e.g., Wholey, Padman, Hamer, & Schwartz, 2001) *[Healthcare organizations often serve as public-sector-like organizations;* ***public role****]*
Size		√	Size or scale of the healthcare organization (e.g., Yoon et al., 2012)
Staff relationships	√		The degree to which clinical staff and administrative staff within the healthcare organization have harmonious relationships *[Because of the high importance and professionalism of the core operation (*i.e.*, medical activities) in healthcare organizations, medical staff have a substantial impact on the administration or management activities;* ***medical and clinical role****]*
Strategic importance of IT		√	The degree to which IT is an integral part of the healthcare organization's corporate strategy and business success (e.g., Mills et al., 2010)
Teaching status	√		Degree of the healthcare organization's involvement in academic and research activities in medical areas (e.g., Kazley & Ozcan, 2007) *[Healthcare organizations take responsibility for teaching medical knowledge and/or contributing to research;* ***public role****]*
Resources			
Commitment		√	Extent to which all units in the healthcare organization commit to the IT adoption project (Spinardi, Graham, & Williams, 1997)

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	*no*	
Financial resources		√	Availability of general financial resources for the adoption and use of the IT artifact (e.g., Cao et al., 2012)
Former experience		√	Extent of the healthcare organization's previous experience with the use or adoption of the IT artifact (e.g., Johnson, Murphy, McNeese, Reddy, & Purao, 2013)
IT capabilities		√	The availability of IT-related resources, capabilities, expertise, knowledge, or skills within the healthcare organization (e.g., Wholey et al., 2001)
IT budget		√	The healthcare organization's budget and spending for IT or IT-related activities (e.g., Baker, Song, Jones, & Ford, 2008)
IT sophistication		√	The level of sophistication in the healthcare organization in terms of IT artifacts (e.g., IT infrastructure), IT usage and IT management (e.g., Lai et al., 2014)
IT staff		√	The availability of qualified IT staff within the healthcare organization (e.g., Yoon et al., 2012)
Knowledge about own business		√	Degree to which one's own business process in the healthcare organization is understood (Silva, 2002))
Medical staff	√		The availability of staff in the healthcare organization's medical areas, including doctors (Simon et al., 2007) and nurses (Poon et al., 2006) *[The availability of high-quality medical staff from internal and external sources for the healthcare organization as relevant sources from the medical perspective;* ***medical and clinical role****]*
Project team competence		√	Perceived competence (e.g., skills, knowledge) of the healthcare organization team responsible for IT adoption (e.g., Yang et al., 2013)
Presence of champions		√	The existence of champions within the healthcare organization for the adoption of IT artifacts (e.g., Lee & Shim, 2007)
Slack resources		√	The availability of slack organizational resources (e.g., time and human availability) for the adoption of the IT artifact (e.g., Peng & Kurnia, 2010)
Space		√	The availability of physical space in the healthcare organization (Lorence & Spink, 2004)
∑	13	21	
Category: environment			
Care system maturity	√		Perceived degree of how efficiently the healthcare system within a region is organized (Alkraiji et al., 2013) *[Because of the high complexity of medical activities, the care system within a region needs effective and efficient organization/coordination; moreover, the central organization of the care system ensures care service quality to the public;* ***medical and clinical role*** and ***public role****]*
Competitive pressure		√	The level of perceived pressure by the healthcare organization from competitors within the industry (e.g., Li, Chang, Hung, & Fu, 2005)
Environmental uncertainty		√	Perceived uncertainty of the region in which the healthcare organization is located (Kazley & Ozcan, 2007)
Penetration of health insurance	√		The rate of (efficient) health insurance in the industry and insurers cooperation with the healthcare organization (Zhang et al., 2013) *[The degree to which a certain area relies on public welfare and/or social resources to receive or maintain healthcare services;* ***public role****]*
Industry standards		√	The availability of (specific) IT industry standards to which the use of the IT artifact could adhere (e.g., Peng & Kurnia, 2010)

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	***no***	
IT artifact penetration		√	Extent to which healthcare organizations in the industry generally use or tend to use the to-be-adopted IT artifact (e.g., Potančok & Voříšek, 2015)
Managed care pressure	√		The perceived external pressure of reducing the cost of providing healthcare while improving the quality of care in the healthcare organization (Wang, Wan, Burke, Bazzoli, & Lin, 2005) *[Requirement to deliver high-quality healthcare services with minimal resources to generally benefit the public;* ***public role****]*
Market maturity		√	The maturity of IT market conditions, particularly including the general availability of IT products and viable vendors (e.g., Bodker, 2002)
Related references	√		The availability of the successful adoption and use of the IT artifact by other clients with highly similar profiles (e.g., geographic area, size) to the healthcare organization (e.g., Baird, Furukawa, & Raghu, 2012) *[High heterogeneity of healthcare organizations caused by different medical focuses and large differences between different medical focuses;* ***medical and clinical role****]*
Ruralness	√		Degree of the rural character of an area in which the healthcare organization is located (Wang, Wang, & Moczygemba, 2014) *[An area's medical service process depends on its health conditions and other environmental factors (*e.g.*, infrastructure); high dependency of the healthcare organization on social resources in its area;* ***medical and clinical role*** and ***public role****]*
Resources			
Industrial IT infrastructure	√		Maturity of IT infrastructure in the industry that supports the healthcare organization in terms of IT adoption, including IT resources (e.g., hardware infrastructure) and IT professionals (Singh, Mathiassen, & Mishra, 2015) *[High dependency of the healthcare organization on social IT resources in its area; the healthcare organization's IT infrastructure is often centrally built by the industry or heavily relies on the shared resources of the industry;* ***public role****]*
Special funding	√		Availability of specific financial resources from the industry or other external public sources for the adoption and use of the IT artifact, including financial support (e.g., Nielsen & Mengiste, 2014) and additional reimbursement from governmental organizations (e.g., Yoon et al., 2012) *[The industry or social support for the healthcare organization to reach public interest purpose;* ***public role****]*
∑	7	5	
Category: data/information			
Data/information centralization	√		The degree to which data and information are centrally processed and stored (Bernsmed, Cruzes, Jaatun, Haugset, & Gjaere, 2014) *[Data and information in healthcare are traditionally stored and processed in a decentralized manner due to the large size of medical data and significant divergence in the requirements of different medical areas;* ***medical and clinical role****]*
Data digitalization	√		The degree to which the data used by the healthcare organization is digitalized (Lorence & Spink, 2004) *[Paper-based form of data or information is popular or occasionally preferred in medical/clinical activities despite the use of IT;* ***medical and clinical role****]*

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	*no*	
Data/information processing needs	√		Demand for data or information for the provision of care services, teaching activities, or coordinated care (e.g., Wang et al., 2005) *[Medical/clinical activities are highly data-oriented or information-intensive;* ***medical and clinical role****]*
Data interoperability	√		Concerns about data not being smoothly exchanged or integrated as required with different internal or external sources with the adopted IT artifact (e.g., Dixon et al., 2013) *[Medical activities need collaboration among different stakeholders, units, and/or organizations that is based on intensive data exchange and sharing;* ***medical and clinical role****]*
Privacy	√		Concerns that personal health-related data or other sensitive information are collected, stored, and/or used in an improper manner or without an appropriate disclosure control *[Data in the healthcare organization is the most sensitive and the related privacy issues have high social impact; moreover, medical data are under strict government supervision;* ***public role****]*
Security	√		Concerns about improper or insufficient protection of data or information from unauthorized use, manipulation, or other undesired actions (e.g., Sultan, 2014) *[Clinical decisions depend heavily on data; manipulated data can negatively influence the quality of care and lead to medical errors; healthcare organizations' data are extremely sensitive and the privacy issues related to such data have a high level of social impact; moreover, medical data are under strict government supervision;* ***medical and clinical role*** and ***public role****]*
∑	6	0	
Category: stakeholders			
Administrator			
Administrator's committee participation	√		The extent to which a healthcare organizational manager participates in policy committees for medical matters (Kimberly & Evanisko, 1981) *[Healthcare organizations are strictly regulated by different regulations or policies;* ***public role****]*
Administrator's cosmopolitanism		√	The extent to which the healthcare organization manager has contacts with professional colleagues outside the immediate work setting (Kimberly & Evanisko, 1981)
Administrator's educational level		√	The highest level of schooling that a healthcare organization manager has attained (Kimberly & Evanisko, 1981)
Administrator's involvement in medical activities	√		The extent to which the healthcare organization manager is involved in daily medical activities or tasks (Kimberly & Evanisko, 1981) *[Because of the high professionalism of the core operation (*i.e.*, medical activities) of the healthcare organizations, administrators are often involved in daily medical activities to better understand and operate the business;* ***medical and clinical role****]*
Assertiveness of top management		√	The degree to which the healthcare organization's management takes action or makes decision assertively and independently (Leidner, Preston, & Chen, 2010)
CIO's innovativeness		√	The extent to which the healthcare organization's CIO tends to accept and use innovative technologies (e.g., Lian et al., 2014)
Existence of IT officer		√	The existence of the role of an information officer in the healthcare organization (Baird et al., 2012)

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	*no*	
Manager's education substance	√		The degree to which the healthcare managers are trained specifically in administration (Kimberly & Evanisko, 1981) *[Because of the high professionalism of the core operation (i.e., medical activities) of the healthcare organizations, healthcare organizations often assign physicians as administrators who can better understand their daily business;* ***medical and clinical role****]*
Manager's innovativeness		√	The extent to which the healthcare organization's manager tends to use innovative technologies (e.g., Hung et al., 2010)
Manager's tenure		√	The length of the healthcare organization manager's affiliation with the organization (Kimberly & Evanisko, 1981)
Strategic importance of IT officer		√	The degree to which the healthcare organization's IT manager is a key strategic leader within the organization (e.g., Leidner et al., 2010)
Top management attitude		√	The degree to which top management generally views IT innovation as an essential component of organizational success (e.g., Leidner et al., 2010)
Top management IT skills		√	Perceived top management knowledge of general IT, IT solutions or IT management practices (e.g., Lin, Lin, Roan, & Yeh, 2012)
Top management support		√	The degree to which healthcare organization managers support the use or adoption of the IT artifact (e.g., Lian et al., 2014)
Patient			
Elderly patients	√		Percentage of the patients who are older than 65 (Baird et al., 2012) *[Elderly patients need more intensive or otherwise special healthcare services;* ***medical and clinical role****]*
Insured patients	√		Percentage of patients who have health insurance (e.g., Baird et al., 2012) *[The core business of the healthcare organizations also relies on public resources;* ***public role****]*
Patient educational level	√		The average level of schooling that a healthcare organization's patients have attained (e.g., Baird et al., 2012) *[The attributes of patients influence their health conditions and the related process of medical services;* ***medical and clinical role****]*
Patient employment rate	√		The level at which the healthcare organization's patients are employed (Baird et al., 2012) *[The attributes of patients influence their health conditions and the related process of medical services;* ***medical and clinical role****]*
Patient income	√		The income level of the healthcare organization's patients (Baird et al., 2012) *[Patients' attributes influence their health conditions and the related process of medical services;* ***medical and clinical role****]*
Patient preference	√		Degree to which patients tend to support the use of or be satisfied with the adoption result of the IT artifact, (e.g., Khoumbati et al., 2006) *[Health-related activities, including the use of health IT, are (should be) patient-oriented;* ***medical and clinical role****]*
Patient sovereignty	√		Perceived degree to which patients have high autonomy regarding the data and/or process in the use of the IT artifact (e.g., Bernsmed et al., 2014) *[Health-related activities, including the use of health IT, are (should be) patient-oriented and the data from medical activities are (should be) owned by patients;* ***medical and clinical role****]*
Policy maker			
Central push		√	Perceived extent to which the industry policy maker supports (e.g., Potančok & Voříšek, 2015), promotes (e.g., Lin et al., 2012) or pushes (e.g., Mills et al., 2010) the adoption of the IT artifact

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	*no*	
Mandate	√		The extent to which policy makers enforce the use or non-use of the IT artifact (e.g., Spinardi et al., 1997) *[Healthcare organizations are strictly regulated by different regulations or policies, including those that impact IT activities;* ***public role****]*
Physician			
Chief of medicine's cosmopolitanism	√		The extent to which the chief of medicine in a healthcare organization has contacts with professional colleagues outside the immediate work setting (Kimberly & Evanisko, 1981) *[Because of the high professionalism of the core business of healthcare organizations, physicians are often involved in decision making;* ***medical and clinical role****]*
Chief of medicine's tenure	√		The duration of the chief of medicine's affiliation with the healthcare organization (Kimberly & Evanisko, 1981) *[Because of the high professionalism of the core business of the healthcare organizations, physicians are often involved in the decision making;* ***medical and clinical role****]*
Involvement in administration	√		The degree to which the healthcare organization's key physicians take responsibility for healthcare organization management or are involved in decision making (e.g., Yang et al., 2013) *[Because of the high professionalism of the core business of the healthcare organizations, physicians are often involved in the administration for a better understanding of the business;* ***medical and clinical role****]*
Physician's innovativeness	√		The extent to which the healthcare organization's physicians tend to use innovative technologies (Simon et al., 2007) *[Because of the high professionalism of the core business of the healthcare organizations, physicians are often involved in the decision making;* ***medical and clinical role****]*
Physician's intention for social gains	√		Degree to which physicians intend to gain social benefits (e.g., reputation) in their field by using the IT artifact (Compagni, Mele, & Ravasi, 2015) *[Success in healthcare depends heavily on social impact;* ***public role****]*
Physician support	√		The degree to which the use of the IT artifact is supported by (key) physicians of the healthcare organization (e.g., Paré & Trudel, 2007) *[Because of the high professionalism of the core business of the healthcare organizations, physicians are often involved in the administrative process for a better understanding of the business;* ***medical and clinical role****]*
User			
Satisfaction with existing IT		√	Users' degree of satisfaction with the current information systems in healthcare organizations (Cao et al., 2012)
User involvement		√	Degree to which users are involved in the project for the adoption of the IT artifact (e.g., Liu, 2011)
User support		√	Degree to which the user supports the adoption of the IT artifact (e.g., Lai et al., 2014)
User's willingness to change		√	Extent to which users are willing to accept the change caused by the IT artifact (Alharbi, Atkins, & Stanier, 2016)
Vendor			
Business interdependency	√		The degree to which the healthcare organization is strategically related to its IT vendor or has a more complex business relationship with the IT vendor (e.g., Yang et al., 2013) *[Health-related services, including the use of health IT, require a high degree of collaboration between different organizations;* ***medical and clinical role****]*

Table S.2 Continued

Master variable	Industry-specific?		Definition *[Description of the industry specificity when applied]*
	yes	***no***	
Physical distance		√	The physical distance between the healthcare organization and the IT vendor (e.g., Bodker, 2002)
Possibility of on-site audit		√	The possibilities provided by the vendor for on-site audit activities (Bernsmed et al., 2014)
Role multiplicity in healthcare	√		Number of different vendor roles at the same time (e.g., IT provider and healthcare service provider) *[Because of the high degree of regulations in the healthcare industry and high professionalism of healthcare services, health IT is occasionally outsourced to organizations with certain functions in the healthcare organization (*e.g*., another healthcare organization);* ***medical and clinical role*** and ***public role****]*
Simplicity of the vendor side		√	Degree to which that the IT vendor is independent and does not employ third parties to deliver IT services (Bodker, 2002)
Trust		√	The degree to which the vendor is trustworthy (e.g., Randeree et al., 2005)
Uncertainty about contract fulfillment		√	Evidence of contract fulfillment by the IT vendor is lacking (Bernsmed et al., 2014)
Uncertainty about vendor lock-in		√	Uncertainty about a vendor's activities that impedes the healthcare organization's ability to use another vendor without substantial switching costs or effort (Sultan, 2014)
Uncertainty about vendor's stainability		√	Uncertainty about the vendor's ability to remain viable in the market (Sultan, 2014)
Vendor's medical knowledge	√		Level of provider's special knowledge or knowhow in medicine (e.g., Reddy et al., 2008) *[Because of the high degree of the professionalism of healthcare, health IT providers often need special medical knowledge;* ***medical and clinical role****]*
Vendor competence		√	Availability of vendor's IT expertise (Alharbi et al., 2016), experience (Low & Chen, 2012), and/or capabilities (Li et al., 2005) that support the adoption of IT artifact by healthcare organization
Vendor push		√	Degree to which vendors use marketing activities to promote the use of the IT artifact (Lee & Shim, 2007)
Vendor support		√	Degree of the IT vendor's support for the healthcare organization, including technical and business support that are related to the adoption of the IT artifact (e.g., Li et al., 2005)
∑	19	26	

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4. Exploring Cloudy Collaboration in Healthcare: An Evaluation Framework of Cloud Computing Services for Hospitals

Paper 3

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Exploring Cloudy Collaboration in Healthcare: An Evaluation Framework of Cloud Computing Services for Hospitals

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Abstract

Cloud computing (CC) is regarded as having the potential to facilitate collaboration in the hospital sector. Yet, adoption of cloud computing services (CCS) in hospitals is low. While a well-designed evaluation of CCS can promote informed adoption decision-making, research on CCS evaluation in the hospital sector is insufficient. To address this research gap, we propose an evaluation framework (EF) of CCS for hospitals. Grounded in the human, organization and technology-fit model, our EF employs six dimensions to evaluate how a CCS facilitates collaboration in hospitals. By applying our EF to 38 identified CCS for hospitals, we demonstrate its efficacy. Our research contributes to both practice and research. For practice, our EF can be used to screen available CCS for hospitals and thus expedite cloud adoption processes. For research, our EF unfolds the complexity of CC in healthcare and is of particular relevance for IS research in healthcare.

1. Introduction

Cloud computing (CC) is an emerging IT service paradigm that enables users to gain on-demand access to a shared pool of configurable computing resources, such as networks, servers, storage, and applications [1]. In particular, CC is capable of enhancing the exchange and sharing of data between disparate health information systems (HIS) [2] and enables access to healthcare-related data and services from anywhere, at any time [3]. Thus, CC has the potential to address the insufficient situation of HIS (cf. Section 2.1) and create a promising future for healthcare entities by facilitating collaboration in healthcare [4].

Collaboration is a joint effort towards a group goal, in which people combine their expertise, insights, and resources and bring them to bear on the task at hand [5]. Today, organizations like healthcare entities frequently face complex problems that are not easily handled or solved by a single individual [6]. Collaboration has therefore become ubiquitous in such organizations [6]. In the healthcare industry, healthcare delivery processes are interwoven with collaborative relationships between health professionals, patients, and other stakeholders (e.g., insurers, researchers) [7]. The healthcare industry is facing challenges of rapidly increasing healthcare demands [8] but dramatically dwindling financial and medical resources [9]. As hard-hit area of these challenges, hospitals are continuously requested to cut healthcare costs while maintaining high quality of care [9]. Consequently, hospitals have begun to seek for more collaboration with each other, hoping that this will increase the outcomes of services [10], minimize duplication and wasting of medical resources [2]. These potentials can be empirically supported by, for example, a recent study, which relies on seven cases of collaboration between hospitals across eleven countries, showing that both patients and hospitals can benefit from enhanced collaboration in healthcare delivery [11].

CC is an effective means to facilitate collaboration within and between hospitals. Yet, adoption of CC in hospitals and in the healthcare industry as a whole is low [12]. In general, a main reason for the low adoption of HIS is the lacking knowledge of decision makers with respect to its potentials and benefits [13]. As for CC in hospitals, this problem might even be more serious since its adoption is particularly complex [4]. Without support, hospital decision makers cannot be expected to gain deep insights into available cloud computing services (CCS) and to get to know results of cloud adoption.

A well-designed evaluation of CCS is considered to be a sufficient way to enable informed decision-making [14]. Based on Song and Letch [15], HIS evaluation can be defined as a process used to identify, measure, and assess the value of an object (e.g., how a CCS facilitates collaboration) in a given context (e.g., the hospital sector) in healthcare. The topic of HIS evaluation has been widely discussed (cf. for example [16]). However, research on evaluation of general HIS as well as CCS in healthcare seems insufficient. Many existing evaluation artifacts of HIS are conceptualized for domains other than healthcare, often resulting in inadequate or unspecific evaluation results [16]. Notwithstanding high

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organizational complexity of hospitals and the people-centered nature of healthcare service delivery, as well as their related collaborative processes [16], existing HIS evaluation studies focus more on technical issues of HIS [17, 18]. Despite the necessity to observe HIS from an information systems (IS) perspective (cf. for example [17, 19]) only little attention has been paid to HIS evaluation from the IS domain, especially for CC in the hospital sector regarding the topic of collaboration.

To address the aforementioned research gap, our research draws on data from a literature review as well as expert interviews and proposes an evaluation framework (EF) to assess how CCS facilitate collaboration in hospitals to the IS community. Grounded in the human, organization and technology-fit (HOT-fit) model [17, 18], our EF focuses on characteristics of CCS deployed in hospitals. By applying our EF to existing CCS for hospitals identified from literature review and expert interviews, we assess and demonstrate efficacy of our EF.

2. Theoretical background

2.1 HIS and CC in hospitals

HIS are a collection of technologies and information systems for transmitting and managing health-related information in healthcare [20]. If used properly, HIS are capable of facilitating data and resource sharing between different stakeholders in healthcare [21] and can thereby promote their collaboration. Yet, traditional HIS in many hospitals are suffering from various issues; in particular, high heterogeneity and fragmentation of HIS within or among hospitals [2] and low off-site HIS availability [12] often lead to insufficient exchange of medical and patient data and thus obstruct collaborative processes within or between hospitals [2, 12]. The emergence of CC has brought new opportunities to hospitals [2], which is why it is expected to satisfy hospital's IT needs for collaboration in a more favorable way [2, 4]. In the IS domain, CC has been discussed by a wide range of research publications. These publications mainly focus on technological issues (e.g., [22]), business issues (e.g., [23]), or the conceptualization of CC (e.g., [24]) in a general context. To the best of our knowledge, there is little extant research paying attention to either evaluation of CCS for hospitals or explaining the mechanisms how CC enables collaboration in the hospital sector in detail.

2.2 The HOT-fit model

Theoretical foundation of our research is the HOT-fit model [17, 18]. The HOT-fit model builds on two established IS theories, namely the DeLone and McLean Model of IS Success [25] and the MIT90s framework [26]. The HOT-fit model is specifically designed to improve research related to HIS evaluation and its application in healthcare has been demonstrated [18]. Contrary to many insufficient IS evaluation methods (cf. Section 1), the HOT-fit model does not overemphasize the role of technology. It takes *human (H)*, *organization (O)*, and *technology (T)* factors into consideration since these three factors are regarded as the essential components of IS [18]. Each of these factors can be dissected into different dimensions. The HOT-fit model depicts that dimensions of factor *T* affect dimensions of factors *H* and *O*, while dimensions of factors *H* and *O* influence *net benefits* of a HIS (c.f. [17, 18] for more detailed explanation). Moreover, the HOT-fit model stresses the role of relationships between every two factors, which are defined as *fit* between them. In the HOT-fit context, the concept of *fit* is considered as the ability of *H*, *O*, and *T* to align and integrate with each other [17, 18].

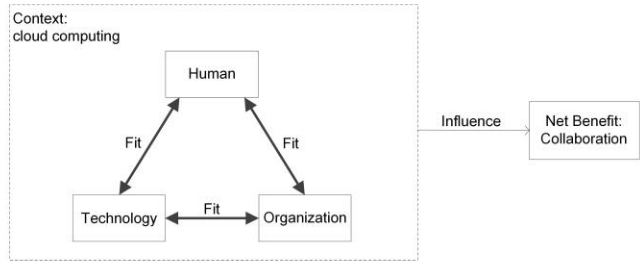

Figure 1. Adapted HOT-fit model

The HOT-fit model is rather deemed an overarching framework for HIS evaluation, and it can and should be applied in a flexible way, for different purposes, and in specific contexts [18]. Thus, we adapt it to comply with the purpose and context of our research, namely to evaluate how CCS facilitate collaboration in hospitals. As outlined in Figure 1, we consider collaboration as the *net benefit* that can be facilitated by CC. In line with its original model, our adapted HOT-fit model demonstrates that collaboration in hospitals can be influenced by CC *technology*, *humans* who use CCS, and hospitals (i.e., *organizations*) in which CCS are deployed, including their related service processes. The links *fit* are interpreted as integration and cooperation of two different factors in the model, implying the importance of collaboration between these single factors (i.e., *H*, *O*, and *T*) for the achievement of overall collaboration in hospitals.

The adapted HOT-fit model is in line with the views of a wide range of previous studies on collaboration in healthcare, which point out that human, organizational and technological factors are key participants of a collaborative activity in modern healthcare and correlation and cooperation between them are able to smoothen and thus improve the collaboration process [7, 19, 27, 28]. Therefore, we can argue that the adapted HOT-fit model is appropriate to serve as a theoretical foundation for the development of our EF.

3. Research design

We applied a three-stage approach for our research. In the first stage, we conducted a review of extant literature as well as eleven semi-structured expert interviews, thus drawing data from theory and practice. We differentiated identified data between a *training dataset* and a *test dataset*. Data from literature belonging to the *theoretical* category (cf. Section 3.1.1) was included in the *training dataset*, while the *test dataset* covered data from literature falling into the *empirical* category (cf. Section 3.1.1) and from expert interviews (cf. Section 3.1.2). Following the guidelines of Fu et al. [29], we utilized the *training dataset* to develop an EF of CCS for hospitals in the second stage. Finally, we assessed the resulting framework by applying it to identified CCS for hospitals represented by the *test dataset*.

3.1 Data collection

3.1.1 Literature review. Our literature review process was oriented towards the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [30]. An overview of the literature review is given in Figure 2.

To identify research articles addressing the topic of CC in hospitals, we searched pertinent scientific literature databases covering a wide range of journals and conferences in the domains of IS, computer science, and medical informatics. Included databases were ACM Digital Library, AIS Electronic Library, EBSCOhost, Emerald Insight, IEEE Xplore Digital Library, Proquest, PubMed, and ScienceDirect.

We searched title, keywords, and abstract using the search string: *(cloud OR "software as a service" OR software-as-a-service OR SaaS OR "platform as a service" OR platform-as-a-service OR PaaS OR "infrastructure as a service" OR infrastructure-as-a-service OR IaaS) AND (hospital* OR clinic* OR inpatient OR in-patient)*. After removing duplicates, a sample of 3334 publications remained, which were then screened by two researchers independently.

Publications were screened using title, abstract, keywords, and full texts. Ineligible articles were excluded by applying predefined exclusion criteria. Accordingly, we excluded all articles that were not published within the last 10 years (*not up-to-date*), are *not in English*, *not peer-reviewed*, or *off-topic*. After the

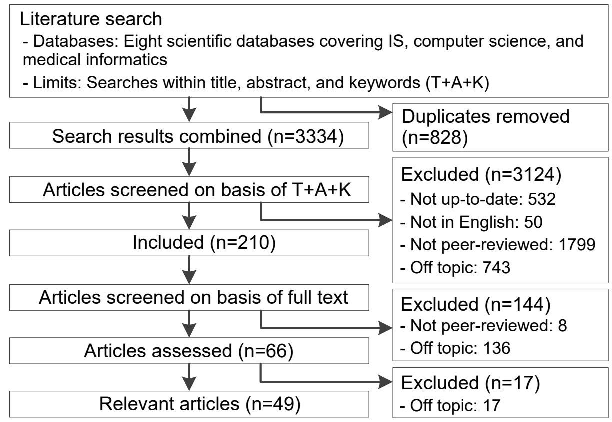

Figure 2. Flow diagram of inclusion/exclusion and literature analysis

literature screening, 3268 articles were excluded from further considerations, while 66 articles remained and were analyzed in detail.

During the analysis of remaining research articles, we identified 17 additional articles that were off-topic, resulting in a final sample of 49 articles to be analyzed in detail. Purpose of the literature analysis was two-fold. First, we pursued characteristics of CC in hospital contexts from a theoretical perspective. These characteristics represent an idealized or desired status of CCS for hospitals based on the current status of CC, providing a solid basis for the development of our EF. Second, we aimed to locate concrete applications of CC in hospitals as well as their characteristics from literature, used to assess the resulting EF. Accordingly, we classified the literature into two categories: *theoretical* and *empirical*. The *theoretical* category covered articles delivering general statements about CCS in hospitals (e.g., [31]) or proposing CCS that are not yet deployed in practice (e.g., [2]), while the *empirical* category contained articles describing concrete CCS for hospitals (e.g., [32]). We observed that some articles deliver general statements or features about CC and then apply them to concrete CCS for hospitals (e.g., [33]). These articles are rather considered as special cases of the *empirical* category and thus also fall in it. In total, 24 of the 49 eligible articles were classified as *theoretical* and 25 as *practical*.

Two researchers separately read all eligible articles to identify relevant statements related to characteristics of CCS for hospitals. Each relevant statement was extracted and turned into one or more pieces of code that represents a characteristic of the described CCS. We compared and aggregated all codes derived by both researchers in order to generate a master list of characteristics that summarizes our analysis results. In total, our master list comprises 685 codes that represent characteristics of CCS addressed by the identified literature.

3.1.2 Expert interviews. We conducted eleven semi-structured expert interviews to identify CCS and their characteristics from practice. They were used to assess the resulting EF. For conduction of expert interviews as well as for analysis of interview results, we followed the best practices by Kvale [34].

We chose experts engaged in IT activities in hospitals for our interviews, who have already used or provided CCS. Interviewees were selected with the aim of developing a diverse pool of experts to gain insights from different perspectives (see Table 1). Accordingly, we did not only include experts with a strong technical background (e.g., i07), but also those who are responsible for management on strategic (e.g., i11) or operational level (e.g., i03). Moreover, we involved an IT project manager from the local public health department (i.e., i08), who can provide insights into the perspective of governmental health authorities. On average, interviewees had a work experience of 12 years. All interviewees' organizations were located in China.

Our interviews focused on experts in China due to three reasons. First, China is a representative example of CC market that has been rapidly expanding in the past few years. A recent report by IDC [35] indicates that, in comparison to the previous year, the Chinese cloud market has increased by 61.9% in 2014 and reached USD 902.8 million. Second, the Chinese healthcare industry is accelerating the adoption and utilization of HIS [36]. As part of this effort, China is actively trying to leverage CC to enable collaboration in the hospital sector and to promote exchange and access of medical data between hospitals [36]. Third, the adoption of CC for the Chinese healthcare industry is being supported by a host of "big players" in the international CC market, including IBM, Cisco, AT&T, Microsoft, and Dell, who are believed to bring numerous existing CC products and best practices to the Chinese CC market as well as healthcare industry [36]. Therefore, we argue

Table 1. Interviewee details

ID	Job title	Organization
i01	CIO	Hospital
i02	Head of IT Department (Dep.)	Hospital
i03	Project Manager	HIS Provider
i04	Staff at New Media Dep.	Hospital
i05	Head of IT Dep.	Hospital
i06	CEO	HIS Provider
i07	Senior IT Staff	Hospital
i08	IT Project Manager	Health Dep.
i09	CIO	Hospital
i10	Senior IT Staff	Hospital
i11	Vice Director	Hospital

that CC experts from the Chinese healthcare industry are familiar with and can thus provide insights of existing CCS in hospitals for our research.

Previous to the formal interviews, we developed an interview guide, which was validated and revised by two internal validation interviews. Based on the interview guide, we asked each interviewee to enumerate all concrete CCS existing in hospitals, including but not limited to those related to their own organization. Afterwards, interviewees were asked to describe how each enumerated CCS works as well as to outline all of its characteristics. These characteristics covered CCS' properties that can be utilized to facilitate collaboration in hospitals. Expert interviews were conducted between December 2014 and January 2015. They had an average duration of 59 minutes. All interviews were recorded and the recordings were transcribed.

Two researchers read the transcripts carefully to extract CCS enumerated by the interviewees and assigned the corresponding statements to each of the CCS. To ensure consistency of our data basis, both researchers applied the same coding technique as in the literature review to analyze extracted statements. As a result, we obtained a list of 221 codes representing characteristics of 13 CCS for hospitals. An overview of identified CCS can be found in the appendix.

3.2 Evaluation framework development

Our development process was guided by Fu et al. [29], who highlight that the design of an evaluation should be led by a mental model representing a basic idea of the evaluation and completed by proposing frameworks or toolkits embodying this idea. For our research, we employed the adapted HOT-fit model described in Section 2.1 as a mental model and relied on data derived from literature to develop an EF.

We focused on codes belonging to research articles in the *theoretical* category (cf. Section 3.1.1) since they reflect an idealized or desired status of CC and can serve as benchmarks for CCS in practice. Two researchers reviewed these codes and classified them into the following seven categories based on their interpretations: *H*, *O*, *T*, *human organization fit (HO-fit)*, *human technology fit (HT-fit)*, *organization technology fit (OT-fit)*, and *irrelevant*. The first six categories stand for three basic factors and their relationships in the adapted HOT-fit model (cf. Section 2.2), which can be utilized to facilitate collaboration in hospitals. For example, the code "real-time data-sharing" represents a technological feature of CCS that relates to enabling collaboration and was classified into category *T*, while the code "patient-centered service process" indicates a relationship between human and the process in an organization during collaboration and can thus be classified into category *HO-fit*. The last category *irrelevant* encased characteristics of CCS that are not directly linked to the concept of collaboration. Accordingly, codes like "flexible pricing model" and "high service level" fell in this category and were excluded from further analysis.

We successively analyzed the codes in each of the six remaining categories. Grounded in our mental model, we derived one core characteristic of CCS for each category. These core characteristics typify the features of CC that can be utilized to facilitate collaboration in hospitals. Therefore, they served as concrete dimensions of our EF to assess CCS. Based on the related codes, we also defined a three-level measurement scale for each of the derived dimensions. The measurement scale is used to assess the extent to which a CCS possesses this characteristic (dimension).

3.3 Evaluation framework assessment

We assessed the resulting EF by applying it to identified CCS from both literature and expert interviews. We used a sample of 38 concrete CCS for hospitals captured by the *test dataset*, of which 25 were identified from literature and 13 from expert interviews (cf. Section 3.1). Two researchers separately reviewed the codes assigned to these CCS and evaluated them by applying the six derived dimensions and their defined measurement scales (cf. Section 3.2) to the CCS. To ensure inter-rater reliability, we employed Janson's and Olsson's ι, a multivariate extension of Cohen's κ for multiple judges on the same scale [37], to evaluate the assessment process. As a result, we reached a score of ι=0.7385, indicating a "substantial" agreement between both researchers [38]. Differences were resolved through discussion. After the assessment process, no changes were made regarding the resulting EF in the last stage.

4. Research results

4.1 Evaluation framework description

Our EF contains six dimensions, which represent core characteristics of CC that, based on our literature review results, facilitate collaboration in hospitals. Each dimension possesses a three-level measurement scale (i.e., +, -, and ○), used to differentiate and thus evaluate a CCS's degree of fulfillment of a certain dimension/characteristic. The level "+" indicates the most desired or idealized fulfillment degree of a CCS for a certain dimension, which does not diverge from the current status of CC according to the literature, while "-" stands for the lowest possible degree a CCS could ever reach in the dimension and "○" is seen as a middle or neutral level between "+" and "-".

(a) User variety (uv). This dimension represents the factor *H* in the adapted HOT-fit model and describes properties of users of a CCS. Due to their high scalability and accessibility [1], CCS have the potential to enable a large number of different kinds of (internal or external) users (e.g., physicians, patients, families) to cooperate within a system [39], and thus to facilitate their collaboration [7]. In this dimension, a CCS is assessed as "-" if it allows only one single kind of users (e.g., physicians), as "○" if it is designed for two different kinds of users (e.g., patients and physicians), and as "+" if it supports more than two kinds of users (e.g., hospital administrators, physicians, and nurses).

(b) Process perimeter (pp). This dimension relates to the factor *O* since it addresses the process in an organization (e.g., a hospital). CC enables access to services or data, without consideration of user's geographical location [3]. This eliminates geographical constrains, expands the perimeter of a medical process, and thus promotes collaboration between different organizations [27]. In *pp*, the level "-" indicates that the process supported or realized by a CCS is limited to a single hospital, "○" denotes that the process involves a specified group of hospitals or organizations, while "+" represents a process, on which no organizational and geographical restrictions are imposed.

(c) Data sharing degree (dd). The third dimension highlights the degree of data sharing of a CCS between users and thus refers to the factor *T*. Data sharing is the essence of collaboration supported by HIS [28]. Indeed, one of the most valuable advantages provided by CC is an improved data sharing ability of HIS in hospitals [31]. Accordingly, a CCS is regarded as having "-" in this dimension if it does not support data-sharing between users, "○" if data-sharing is asynchronous, and "+" if data sharing is synchronous (e.g., real-time data exchange).

(d) Patient involvement (pi). Besides collaboration (cf. Section 1) another nature of healthcare service delivery is its customer orientation [16], implying a high demand of patient embedment in hospitals' medical processes and thus collaboration between patients and hospitals [60]. The CC paradigm is service-oriented [1] and can thus integrate the customer-oriented nature into its process. This CC characteristic is reflected in *pi*, which is in line with the view of a *HO-fit*. In this dimension, we observe a CCS as possessing "-" given that no patient involvement occurs throughout its process. If a patient is involved in the process only when necessary (i.e., passive patient involvement), a CCS is assessed as "○". A CCS with level "+" means that this CCS is patient-facing (i.e., active patient involvement, also cf. Section 5.1) [61].

(e) Device integration (di). The dimension *di* describes the ability of a CCS user device to integrate with users and thus represents the *HT-fit*. In general, a barrier impeding the use of HIS and hence also its potential of enabling collaboration is the alteration of users' traditional workflow paradigm [62]. In other words, users often have to adapt themselves to the technologies (cf. e.g., [63]) leading to reluctance to adopt HIS. CCS can be accessed by a wide range of devices [1] and thus have the potential to support devices with a high degree of integration with humans to increase their flexibility as well as possibilities to collaborate [60]. In this dimension, a CCS is assigned to "-" if it has no specific adaption to user devices, "○" if it is adapted to common mobile devices (e.g., smart phones) increasing the mobility of service, and "+" if it implements sophisticated human-computer integration technologies like sensors or wearable computer technologies enabling service access in a more unrestrained and unobtrusive way.

Table 2. Results of the EF assessment

Hospital CCS		uv	pp	dd	pi	di	si
[8]		○	○	+	-	○	+
[32]		-	○	○	-	-	-
[40]		+	-	-	-	-	○
[12]		+	○	○	-	-	+
[41]		-	-	○	-	-	-
[42]		-	○	+	-	○	○
[43]		-	○	+	-	-	○
[44]		-	○	○	-	○	○
[45]		-	○	○	-	+	+
[46]		-	-	+	○	+	-
[47]		-	-	○	-	-	○
[39]		-	○	+	-	○	-
[33]		-	-	○	-	+	-
[48]		-	○	+	○	○	+
[49]		-	-	+	-	○	○
[50]		○	-	○	-	○	-
[51]		○	-	+	+	○	○
[52]		○	-	○	-	-	○
[53]		-	-	+	-	-	○
[54]		○	-	-	+	+	+
[55]		-	-	+	○	-	+
[56], c02, c05		-	-	○	-	○	-
[57]		○	-	+	+	+	+
[58]		-	+	○	-	-	+
[59]		-	-	○	-	○	+
c01		○	-	○	+	○	-
c03		+	-	○	-	-	-
c04, c07		-	-	○	+	○	-
c06		-	-	-	-	○	+
c08		-	○	○	+	-	-
c09		○	○	○	-	-	-
c10		○	-	+	+	+	-
c11		+	○	○	-	-	○
c12, c13		+	-	○	-	-	○
∑: n (%)	-	23(61)	25(66)	3(8)	27(71)	16(42)	16(42)
	○	9(24)	12(32)	23(61)	3(8)	16(42)	12(32)
	+	6(16)	1(3)	12(32)	8(21)	6(16)	10(26)

(Note: Due to rounding, displayed percentages of one dimension might not add up to 100.)

(f) System interoperability (si). This last dimension represents the *OT-fit* view and relates to the ability of a CCS to interoperate with other processes or systems in a hospital. Interoperability is regarded as a challenge existing in many hospitals due to high heterogeneity of different data, systems, and/or processes [2]. By centrally implementing industry standards [4], cloud providers are capable of increasing the interoperability of their CCS. As a result, these CCS are able to cooperate with different systems more smoothly. A CCS is rated with "-" in *si* if it cannot interoperate with any other systems and thus works as a silo, "○" if it can only interoperate with certain predefined systems, and "+", given that it integrates industry standards for interoperability.

4.2 Evaluation framework assessment results

By applying our EF to 38 identified CCS for hospitals from both literature and expert interviews, we assess its efficacy of evaluating how CCS facilitate collaboration in hospitals. The assessment shows that our EF is applicable to all the CCS. The derived dimensions and their measurement scale can fully cover the characteristics of identified CCS, which can be utilized to facilitate collaboration in hospitals. Therefore, we demonstrate the efficacy of our EF.

Table 2 depicts the assessment results. All CCS possess the level "-" in at least one of the six dimensions. More than 60% of the CCS are assessed with "-" in *uv*, *pp*, or *pi*, and more than 40% in *di* or *si*. On average, the percentage of "+" in all six dimensions is less than 20 (18.9%). Our assessment results thus reveal an insufficient situation of addressed CCS regarding their capabilities to support collaboration for hospitals, as discussed in Section 5.

5. Discussion

5.1 Research results

Taking a look at the statistics of the assessment results of our EF (see Table 2), we gain some key insights into the existing CCS for hospitals. In *user variety*, 61% of assessed CCS enable only one single type of users, thus possessing the measurement level "-". Indeed, most of such CCS (e.g., CCS in [44, 46, 49], c02) are designed to be used by physicians. A traditional view about HIS claims that physicians are actually end-users of HIS [64]. Consequently, decision making processes for development or purchase of new HIS that are led by physicians have become a recent development in healthcare [65]. It is therefore not surprising that more CCS have been designed and developed to cater to physicians' needs, as implied by the assessment results in *user variety*. Physicians are usually trained to be self-reliant in thought and action and do not view themselves as being dependent on others in the provision of care [10]. This culture possibly inhibits the realization of desired collaborative healthcare processes enabled by CC, which take different user groups like physicians, nurses, clerical workers, and patients into account [28]. Thus, physicians' reluctance to coexist or interact with other occupational users or even other physicians in the same HIS should receive more attention in future research.

The philosophy of modern HIS has shown a hopeful scene to us: collaboration between different entities is not limited by their geographical locations; boundaries of healthcare services are rather defined by their processes [27]. This scene, however, can be realized by only one CCS, based on the assessment results for *process perimeter*. This CCS, presented by [58], enables users to search and share patient data stored in different participating hospitals without consideration of their locations. Yet, among the 37 CCS that are evaluated as "-" or "○" in *process perimeter*, nine (e.g., CCS in [12, 45, 55], c06) possess "+" in *system interoperability*. This indicates that these CCS are highly interoperable with heterogeneous IS or processes in different organizations. If improved properly, they still have the possibility to integrate with more external systems and thus effectively expand the scope of their care delivery processes.

The *dimension patient involvement* evaluates the extent to which patients are involved in healthcare delivery processes realized or supported by CCS. Only 29% (n=11) of the CCS ensure more or less patient involvement in their processes and are evaluated as "○" (n=3) or "+" (n=8). Nowadays, HIS and related IT services, like CCS, intend to alter patient behavior and change their role in healthcare delivery processes [61]. Patients try to manage their health more autonomously [27] and wish to act more actively in healthcare [61]. A health-related IT service that engages patients and promotes an active role for them can be defined as a patient-facing IT service [61]. Accordingly, there are three categories of patient-facing IT services: *information and transaction*, *expert care*, and *self-care and community* [61]. Our research addresses eight CCS that can be evaluated with "+" in *patient involvement* and thus identified as patient-facing IT services. Among them, c01, c04, c07 and c08 mainly assist patients in booking and managing medical appointments, while CCS in [54] enables patients to manage healthcare data. They can thereby be classified into *information and transaction*. CCS in c10 and [51, 57] provide remote medical consultation services to patients and are thus defined as *expert care*. Besides, CCS in [51] also interacts with external social networks and can thereby fall in category *self-care and community*. In agreement with previous research [61], we cannot identify any CCS that provides patients with "one-stop" service linking all three categories of services. This still reveals a need for further improvement of the CCS that are already regarded to provide patient-facing services based on our evaluation.

We observe that more than half (58%) of the identified CCS adapt themselves to user devices (i.e., evaluated as "○" or "+" in *device integration*). These CCS develop for example specific mobile device applications (e.g., [49]), compress data to accelerate data transfer (e.g., [44]), or implement sensor technologies (e.g., [46]) for user devices. Thereby, these CCS are most likely to increase flexibility and mobility of service access and enhance connections between users and CCS. However, use of mobile or sensor technologies in healthcare is not without challenges [60]. In a recent study, Dehling et al. [66] point out that many extant mobile health apps are probably suffering from data security and privacy issues. For CC in healthcare, data security and privacy are also seen as its Achilles' heel [4, 67]. Whether or not a combination of these technologies will aggravate data security and privacy issues in healthcare and thus impede its dissemination remains to be addressed in further research.

5.2 Contributions and limitations

Our research contributes to both practice and theory. For practice, our EF can support hospital decision makers in evaluating CCS concerning a specific topic (i.e., collaboration) and thus expedite their cloud adoption processes. Our EF evaluates CCS along six different dimensions and can, for instance, be used by hospital decision makers to screen potential CCS according to their own needs.

For theory, our research proposes a useful tool to the IS community to unfold the complexity of CC in healthcare. Our EF concentrates on CC and reflects its specificities in the hospital sector. It needs to be emphasized that our EF is not expected to also cover CCS in other areas due to its specific scope. Yet, our EF is of particular relevance for the IS community, since healthcare represents a substantially different context compared to other areas where IS research is conducted and thus deserves specific attention of IS researchers [9]. Our research is grounded in the HOT-fit model, rooted in two classic IS theories. Although our main research purpose is not to build new IS theories in healthcare, our research adapts the HOT-fit model and employs the adapted model to explain and understand the phenomena of CC in hospitals. Thus, we argue that our research can be classified in the catalog of *Health-IS* research according to Chasson and Davidson [9], in which "authors examine phenomena in healthcare context, using theory to explaining phenomena, possibly extending or building theory in this context" (p. 163). We apply our EF to evaluate CCS identified through a literature review (cf. Section 3.3). Thus, our research can also be considered as a *framework article* in the IS domain synthesizing research literature, because it "constitutes a way of understanding the research within a body of knowledge" [68, p. 41] (i.e., how CCS presented by literature facilitate collaboration in hospitals). In particular, our EF can be defined as a framework that is used to synthesize previous research in an actionable way, because it evaluates how CCS presented by literature facilitate collaboration in hospitals and highlights their strengths and improvement opportunities for researchers and practitioners [68].

The limited number of 11 expert interviews is a limitation of our research, which does not necessarily guarantee that all existing CCS in the hospital sector are fully covered. However, articles from the *empirical* category in our literature review provide us information about further CCS in practice, which can be regarded as a meaningful supplement to our expert interviews. For our expert interviews, we did not include patients on purpose, though the role of patients is an indispensable component of the hospital sector and the use of HIS [7]. Our interviews focus more on interviewees' expertise on CCS for hospitals. Ordinary patients are less likely to provide such expertise or "insider-information" about CCS for hospitals and are thus not defined as experts for our research.

It is noteworthy that our EF serves as a module in a holistic evaluation project of CCS for hospitals since it focuses only on a single aspect of CC (i.e., collaboration). Thus, its evaluation results do not necessarily represent overall quality of a CCS. Future research should make an effort to develop EF that address remaining relevant topics, like CCS' functionalities, or their financial advantages, and combine them with our EF for a more holistic evaluation of CCS for hospitals. Further research could also take specificities from other industries into account. By doing this, the scope of our EF can be expanded and our EF can thereby be utilized to address more general CCS.

6. Conclusion

250 years ago, James Watt used evaluation methods, albeit maybe informal ones, to assess the efficiency of Tomas Newcomen's steam engine [69]. This led to improvement to the Newcomen steam engine, which stands out as one of the notable landmarks in the Industrial Revolution [69]. Today, the emergence of CC is regarded as having the potential to create a promising future for HIS enabling collaboration in healthcare [4]. CC can and should play an important role in the development process of modern healthcare. However, its adoption is still lagging [12]. In this paper, we propose an EF for CCS in hospitals. With our EF, we expect to assist researchers and practitioners in gaining deeper insights into CCS for hospitals, promote their continual improvement, and facilitate adoption of CC in the hospital sector.

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Appendix. Overview of identified CCS from expert interviews

ID	Short Description *[Source (s)]*
c01	A cloud-based clinical information system that enables patients and their relatives to book and manage medical appointments in a hospital, and allows patients to view laboratory reports related to their appointments and upload own image files to support diagnoses *[i01, i07]*
c02	A CCS that allows physicians of a hospital to view and share patient information with each other by using authorized mobile devices from both within and outside the hospital *[i01]*
c03	A cloud-based virtual desktop solution covering all information systems in a single hospital *[i02]*
c04	A medical appointment management tool that enables patients to book medical appointments in a hospital by using mobile devices and view laboratory reports related to their medical appointments *[i02, i10]*
c05	A CCS for physicians in a hospital enabling its users to directly view and share medical images on authorized tablet computers from within or outside the hospital *[i03]*
c06	A cloud-based web service used to support radiology information systems and provide enterprise-wide image processing (e.g., 3D/4D visualization) across clinical care areas *[i03]*
c07	c07 provides same services as c04, deployed, however, in another hospital *[i04]*
c08	A web-based CCS enabling patients to book medical appointments in certain top-rated hospitals *[i04, i08]*
c09	A cloud-based platform provided for small-sized hospitals in a district that enables processing and sharing electronic medical records of patients within these hospitals *[i05]*
c10	A CCS providing remote real-time medical video consultation services for patients; by using sensors, c10 collects and stores vital signs of a patient, supporting the consultation and further clinical activities *[i05, i11]*
c11	An internet-based cloud solution for hospital information systems for several dental hospitals, which integrates all standard applications and information systems of a common dental hospital *[i06]*
c12	c12 provides same services as c03 deployed, however, in another hospital *[i08]*
c13	c13 provides same services as c03 deployed, however, in another hospital *[i09]*

5. Multi-Organizational Multi-Stakeholder Collaboration Systems: An Exploratory Research Study of Design Concerns

Paper 4

Gao, Fangjian; Briggs, Robert O.; Thiebes, Scott; Sunyaev, Ali (2018): Multi-Organizational Multi-Stakeholder Collaboration Systems: An Exploratory Research Study of Design Concerns. In 2019 52nd Hawaii International Conference on System Sciences (HICSS 2019), under review.

Multi-Organizational Multi-Stakeholder Collaboration Systems: An Exploratory Research Study of Design Concerns

Abstract

Collaboration Engineering has focused on collaboration systems for teams, which could also inform large-scale multi-organizational multi-stakeholder (MO-MS) collaborations such as disaster relief, joint ventures, and healthcare. These larger contexts, though, present design concerns beyond those for team collaboration, and not all these concerns are self-evident. This paper explores the design concerns for IT-supported MO-MS collaboration. We selected the healthcare industry as the first exemplar domain for this inquiry mainly because research shows high potential benefits from, and substantial challenges to implementing systems for collaborative healthcare. We draw on an extensive literature review, and 50 semi-structured interviews with experts to discover and validate collaboration challenges presented by in-house and cloud-based IT services for healthcare. We derive an eleven-class typology of design concerns and requirements-elicitation design questions related to MO-MS collaboration. To demonstrate its utility, we draw on exploratory findings to elaborate the generalizable typology with probes specific to healthcare collaboration systems.

1. Introduction

To date, the technical focus of Collaboration Engineering (CE) research has been collaboration systems for teams. That research could also inform collaboration systems for large-scale multi-organizational multi-stakeholder (MO-MS) contexts such as disaster relief, joint ventures, public administration, and healthcare. These larger contexts however, present design concerns beyond those for team collaboration, and not all those concerns are self-evident. This paper investigates design concerns for large-scale IT-supported MO-MS collaboration.

We selected the healthcare industry as the first exemplar domain for this exploration because healthcare faces several global challenges, and there is high potential for collaborative healthcare to mitigate those challenges. Global demand for healthcare is rising as incidents of acute and chronic diseases are accelerating, and populations are aging [1]. As a result, demands for healthcare services are expected to increase by more than 130% within the next 25 years [2]. Meanwhile, dwindling per-capita medical resources and shortages of medicines and healthcare professionals make it increasingly difficult for healthcare organizations such as hospitals and clinics to deliver appropriate services [3, 4].

Collaboration in healthcare (e.g., for medical diagnosis, treatment, case management), supported by appropriate IT, can help to mitigate these challenges. Collaboration in healthcare is associated improved health outcomes in situations where resources are strained [5]. Researchers identify three core collaboration needs for healthcare, i.e. to coordinate collaborators' cooperative activities [6], to exchange structured data [7], and to support collaborators' communication for joint reasoning [8]. Health information systems that afford those capabilities are associated with, for instance, reduced preventable adverse drug reactions [9], decreased duplication of effort [10], and reduced waste of healthcare resources [11].

In many healthcare organizations, though, existing health information systems are not well-suited to healthcare collaboration. A number of systems suffer multiple deficiencies, such as a) inadequate support for the various healthcare roles (e.g., patients, doctors, insurance companies, pharmacists) [12], b) high cognitive overload associated with the exchange of high-volume patient data [13], and c) delayed or incomplete communication among collaborators [14]. These insufficiencies impede collaboration, which fosters medical errors (e.g., misunderstanding caused by incomplete communication) that degrade healthcare and put patients at risk [6]. Such challenges seem to be common across MO-MS domains. It would therefore be useful to answer this research question: *What are the design concerns for collaborative health information systems, and which of those aspects can be generalized across MO-MS contexts?*

In this paper, we draw on an extensive literature review, and on 50 semi-structured interviews with experts to discover and validate collaboration challenges presented by in-house and cloud-based IT services for healthcare. From the findings, we derive a generalizable typology comprising eleven classes of design concerns and design questions related to MO-MS collaboration. To demonstrate the utility of the typology, we analyzed which design questions could be elaborated with domain-specific cues to foster more-complete requirements elicitation in a given domain. We drew on the exploratory findings to create an instance of the generalizable typology elaborated, where appropriate, with prompts specific to the healthcare domain.

2. Research Methods

We conducted a two-year Design Science Research study using the disciplines for Exploratory Research [15] to discover and describe design concerns for MO-MS collaboration, and to formalize them into a generalizable design tool for practitioners and researchers.

We investigated both in-house and cloud-computing services (CCSs) because an increasing number of healthcare organizations (up to 82%) now outsource to complement and improve their in-house IT [16], and CC is becoming their preferred form of outsourcing [17]. Further, many current CCS offerings in healthcare support some degree of collaboration [18]. Including CC could increase the comprehensiveness of our findings.

We began with an extensive review of the Information Systems, Computer Science, and Medical Informatics literatures drawn from several sources i.e., ACM Digital Library, AISeL, EBSCOhost, Emerald Insight, IEEE Xplore Digital Library, Proquest, PubMed, and ScienceDirect. We identified 6,609 potentially relevant articles, and screened them for content relevant to IT-supported collaboration in healthcare that is based on in-house or CCSs. This produced a final list of 100 relevant articles. From these articles, we abstracted six categories of design concerns. A more detailed description of the literature review is available on request.

We then conducted two rounds of expert interviews. The first round focused on capabilities of CCSs in healthcare that support collaborative activities. The interviewees came from healthcare organizations that consumed CCSs, and IT vendors that provided CCSs in China (N=12) and Germany (N=12), as we had access to experts in both countries. The interviews were conducted between Dec. 2014 and Nov. 2015. They had an average duration of 51 minutes. We recorded and transcribed all interviews.

The first-round interviews asked the experts to enumerate all CCSs in healthcare with which they were familiar, including, but not limited to those related to their own organizations. Interviewees were then asked to describe the purpose of each CCS, and the key capabilities of each, with special attention to those targeting collaboration in healthcare.

After 24 interviews, we reached conceptual saturation (i.e., the last few interviews revealed no new concepts) [15], so we ended the first round. We analyzed the interview transcripts and extracted, aggregated, and classified design concerns for collaboration systems in healthcare, and thereby four additional categories of design concerns that we had not discovered in the literature.

We then conducted a second round of interviews to validate results from the literature review and the first round of interviews, and, if possible, to identify further categories of design concerns. Interviewees in the second round were not only health IT experts but also clinical medical professionals who are regular users of health information systems for collaboration. Nine of the interviewees in the second round came from China and 17 from Germany. No interviewees from the first round participated in the second round. The interviews were conducted between Nov. 2016 and Jan. 2017. The average duration was 58 minutes. We recorded and transcribed all interviews.

The second-round interview began by asking the experts to describe the collaboration capabilities a health information system should have. Next, we presented the ten categories from the prior rounds, and asked the experts to evaluate whether, how, and why these categories of concerns were important to collaboration in healthcare. They were also asked whether the ten categories overlooked key concerns.

After 26 interviews, we reached conceptual saturation in the second round. We extracted, aggregate, and classified the concepts in the interview data, which validated the ten categories from the previous steps. Finally, we drew on the Six-Layer Model of Collaboration [19] to add an eleventh category of design concerns that are universal and was suggested by the second round of interviews. A full overview of interviewees and interview questions for both rounds are available on request.

Having synthesized the eleven categories, we returned to the literature and to the interview transcripts to extract a checklist of design questions for eliciting requirements related to each category of concerns. Each question relates to an issue that stakeholders and system designers should consider when designing a MO-MS collaboration system.

Finally, to demonstrate how the generalizable typology could be adapted to a specific MO-MS domain, we returned again to the concepts from the literature and the interviews to define healthcare specific prompts that could be used to encourage a more thorough exploration of requirements for that domain. The next section explains each category, and presents its checklist of general design questions, and, where appropriate, prompts specific to healthcare.

3. Research Results

The first category (Category 0) addresses concerns common to all collaboration systems. These are not unique to the healthcare context, but are nonetheless essential to healthcare collaboration. We organize these concerns around the Six-Layer Model of Collaboration (SLMC) [19, 20]. The remaining ten categories (Category 1 to 10) elaborate Category 0 concepts with concerns that are specific to healthcare context. Category 0 therefore serves as the entry point for the rest of the categories.

Category 0: Collaboration Practices. The Collaboration Practices category addresses concerns that arise when individuals make a joint effort toward a group goal. The SLMC considers design concerns at six different levels of abstraction. The most-abstract is the *Collaboration Goals Layer* (1). A goal is a desired state or outcome. Concerns at this layer address the group goals, the stakeholders, and the private goals that motivate stakeholders to work toward the group goal. The *Group Products Layer* (2) concerns defining and designing the tangible artifacts or intangible states the group will work to create in order to achieve its group and private goals. The *Group Activities Layer* (3) concerns designing the work breakdown structure a group must do to create the group products. The *Group Procedures Layer* (4) concerns the design of techniques and tactics by which the stakeholders will move through each activity in the work breakdown structure. The *Collaboration Tools Layer* (5) considers the design and configuration of apparatus and technologies the group will use to execute its procedures. The *Collaboration Behaviors Layer* (6) concerns designing the constraints for what people should say and do with their tools to instantiate the procedures to move through the activities to create the deliverables to achieve their goals (for example, ‘During the brainstorm, participants should not delete the contributions of others’). Category 0 proposes seven concrete design questions to remind stakeholders to reflect on concerns at all six layers of abstraction (See Table 1).

The Category 0 questions are prerequisites for the questions in the subsequent categories. Interviewee #45 (software provider for nursing work), said, for example: “*Without ground rules and without a definition of collaboration tasks it (collaboration in healthcare) will never work ... Before we start collaboration, our number one question is always whether all goals, rules, processes, activities, and so on have already been clearly defined.”*

Thus, we recognize the Category 0 concerns as meta-requirements for collaboration in healthcare.

Category 1: Role Variety. Role variety concerns the assortment of roles who must be involved in collaborative healthcare, the specific classes of events in which each role must participate, and the capabilities the system must afford to support their involvement in those events. A wide variety of stakeholders with differing interests and expertise must collaborate in healthcare. Interviewee #48, head of a health IT consultancy, stated: *“It’s because we have to integrate different stakeholders with very different interests into one thing.”*

This category of design concerns is often not thoroughly considered in health collaboration system designs. Our interviewees highlighted the patient role as a typical example, noting that systems often precluded their involvement. Interviewee #26 (assistant ophthalmologist) for example, said: *“Even for communication between doctors, I think it is important to involve patients. Because otherwise, for example, the information passed between physicians is just not accurate. It’s second-hand.”*

In Category 1, our design questions (see Table 1) aim to identify roles, and role-based privileges and restrictions that should be offered by health information systems (e.g., role-based enforcement of privacy policies for patient records). Some of the questions are associated with options derived from the literature and the interviews.

Category 2: Service Perimeter. Service Perimeter concerns the variety of entities outside the organization. The findings suggest that, in some cases, a system should be able to accommodate entities in different geographical areas, with differing political conditions, and should accommodate participation by people from different industries because *“People should try get rid of or blur differences [boundaries] that are in conjunction with laws, rules or culture stuff for different organizations”* (Interviewee #32, health IT developer). Collaboration in healthcare often occurs among different organizations across different boundaries, as explained by Interviewee #36 (IT researcher): *“I know someone who is a doctor [in Germany], but has patients in Dubai and Qatar. They swear that German doctors are better than those in Dubai or Qatar. ... He often works [in Germany] together with his patients there, and of course with their local hospitals. I believe the boundaries don’t have to exist.”*

Design questions in Category 2 assist designers to identify and address these possible boundaries.

Table 1. Design concerns and design questions for information systems that support collaboration in healthcare

Category	Design *Question [Aid in Answering the Question, if Applicable]*	Related to
0. Collaboration Practices	Q0.1 What goals do collaborators seek to achieve?	SLMC*
	Q0.2 What deliverables do collaborators need to achieve each goal?	SLMC*
	Q0.3 What work packages must collaborators complete to create each deliverable?	SLMC*
	Q0.4 What procedures must collaborators follow to complete each work package?	SLMC*
	Q0.5 What technological support will collaborators require to execute each procedure?	SLMC*
	Q0.6 What information and data do collaborators need to create each deliverable?	SLMC*
	Q0.7 What must collaborators say and do with the system affordances under what constraints to instantiate each procedure?	SLMC*
1. Role Variety	Q1.1 What are the roles involved in the collaborative activities and what are their interests/goals? [physicians; patients; patients' family members; patients' friends; anesthetists; nurses; midwives; pharmacists; radiologists; orderlies; health workers; healthcare administration staff; researchers; insurance company staff; government staff]	Q0.1
	Q1.2 For each different role, what relevant events are there in the collaborative process? [prevention (e.g. screening); propaedeutic, (e.g. vital signs) measurement; diagnostic (e.g., medical imaging); therapeutic (e.g., chemotherapy); anesthesia (e.g., local anesthesia); surgeries (minimally invasive procedures); nursing (e.g., wound care); administration (e.g., insurance settlement)]	Q0.3
	Q1.3 For each event in the collaborative activities: what roles are allowed and not allowed to participate in?	Q0.7
	Q1.4 For each event in the collaborative activities: if a role is allowed to participate in it, what actions are allowed and not allowed for this role?	Q0.7
	Q1.5 For each event in the collaborative: if a role is allowed to participate in it, what data access actions [view; add; edit; associate; cut; copy; delete] for what data are allowed for this role?	Q0.7
	Q1.6 For each event in the collaborative: if a role is allowed to participate in it, what data and information are preferred by this role?	Q0.6
2. Service Perimeter	Q2.1 What are the outside entities that are involved in the collaborative activities and what are their interests/goals? [hospitals; clinics; laboratories; pharmacies; nursing homes; funeral homes; social welfare departments; aid organizations; law departments; healthcare authorities; insurance companies; research institutes]	Q0.1
	Q2.2 What are the different legal requirements, specifications, or restrictions each outside entity has to follow concerning geographical differences [city level; county level; state level; country level]?	Q0.4
	Q2.3 What are the different legal requirements, specifications, or restrictions each outside entity has to follow concerning industrial differences [healthcare; pharmaceutical; education; financial services; public utilities]?	Q0.7
	Q2.4 What are the different culture elements that should be considered, to which outside entities are subject [distances; time differences; symbols; language; norms; traditions; religions; workplace manners]?	Q0.4
3. Response Times	Q3.1 What is the latency allowed for each event in the collaborative activities?	Q0.4
	Q3.2 What events should be conducted in a real-time manner (e.g., synchronistic interaction with another event)?	Q0.4
	Q3.3 In what situations can the pre-defined event latency vary?	Q0.4
	Q3.4 How should collaborators act if the pre-defined event latency cannot be hold?	Q0.7
4. Device Integration	Q4.1 What kinds of user devices should be supported for accessing the system [stationary devices; mobile devices; wearable devices; no-barrier devices]?	Q0.5
	Q4.2 To what devices should the system specifically adapt?	Q0.5
	Q4.3 What specific tasks in what situations should each supported device afford?	Q0.5
	Q4.4 What data access actions [read; write; edit; copy; delete] in what situations are allowed for each supported device?	Q0.5

Note: * Category 0 builds the idea of the Six-Layer Model of Collaboration (SLMC) by Briggs et al. [20]. Q0.1 concerns *the Collaboration Goals Layer*, Q0.2 *the Group Products Layer*, Q0.3 *the Group Activities Layer*, Q0.4 *the Group Procedure Layer*, Q0.5 and 0.6 *the Collaboration Tools Layer*, and Q0.7 *the Collaborative Behaviors Layer*. Design questions in category 1 to 10 specify the idea related to the SLMC for healthcare settings.

Category 3: Response Times. Category 3 concerns the variety of events to which the health information system will respond, and the capabilities the health information system must afford to attain the minimum necessary response time for each class of organization that should be involved in a collaboration, and the capabilities the system must afford to support their involvement.

Timeliness is one of the most critical indicators of success for collaboration in healthcare: *"To do everything in a timely manner is the basis of collaboration in healthcare. ... Imagine you have*

Table 1. Continued

Category	Design Question *[Aid in Answering the Question, if Applicable]*	Related to
5. System Inter-operability	Q5.1 What are the typical data that are needed for the collaborative activities *[electronic medical records; electronic health records; personal health records; reference data from disease registries; clinical tries data; medication adherence data; administrative data; claims data; health survey data; socioeconomic data (about determinants of health)]*?	Q0.6
	Q5.2 How do structures of the needed data look like?	Q0.6
	Q5.3 For a certain type of data, what are the major systems that create them?	Q0.6
	Q5.4 How does the system use each type of data and what data access actions does the system have to the data *[read; write; edit; copy; delete]?*	Q0.6
	Q5.5 What are internal or external legacy approaches or tools, with which the system needs to interoperate?	Q0.5
	Q5.6 How should the system interoperate with the legacy approaches or tools?	Q0.5
6. Process Adaptability	Q6.1 Under what operative conditions does each work package in collaboration take place *[participants; necessary (medical) resources; medical observations; status of other work packages]?*	Q0.4
	Q6.2 What operative conditions, under which a work package takes place, are likely to change or adapt themselves or have exceptions?	Q0.4
	Q6.3 For the operative conditions that are likely to change or have exceptions, how should changes or exceptions be supported by the system?	Q0.4
	Q6.4 What legal requirements, specifications, or restrictions under which collaboration takes place, are likely to change or adapt themselves?	Q0.4
	Q6.5 For the legal requirements, specifications, or restrictions that are likely to change, how should changes or adaptions supported by the system?	Q0.4
7. User Awareness	Q7.1 What are the defined goals, rules, individual responsibilities, and available resources for each work stage that should be used to inform collaborators?	Q0.3
	Q7.2 What kinds of information is needed by collaborators to know the completion progress of deliverables in each work package *[starting time; utilization of resources; current location; schedule adherence; expected finish time]?*	Q0.2
	Q7.3 What information is needed by a collaborator to know with whom she or he is collaborating and current states of other collaborators' actions?	Q0.7
8. (Patient) Data Integration	Q8.1 What internal and external (patient) data are at least required for collaborative health care that is supported by the system?	Q0.6
	Q8.2 How can the system access or collect the needed (patient) data?	Q0.6
	Q8.3 What needed (patient) data can be produced by the system?	Q0.2
	Q8.4 How are (patient) data produced by system that support future collaborative activities stored and/or updated by the system?	Q0.2
9. Richness of System Cues	Q9.1 For each kind of information and data in the system, which human senses can be used to increase collaborators' perceived richness when processing data *[sight; hearing; taste; smell; touch; balance; acceleration; temperature; proprioception; pain; emotion; further internal senses]?*	Q0.6
	Q9.2 For each kind of data or information, what content forms can increase its richness perceived by collaborators *[texts; images; animations; videos without sounds; videos with sounds; 3D contents; virtual reality contents; digital games; stimulations]?*	Q0.6
10. Concept Clarity	Q10.1 What concepts, statements, or (medical) values in the collaboration process need definitions or clarifications, or are subject to interpretations?	Q0.6
	Q10.2 What concepts, statements, or (medical) values that are produced by the system need definitions, clarifications or interpretations (also for possible future collaborative activities)?	Q0.2
	Q10.3 What are the target user groups for the definitions or interpretations of each (medical) concept or value?	Q0.1
	Q10.4 How should the concepts, statements, or values be defined, clarified, or interpreted for each different target user group *[using semantic standards (e.g. nomenclatures); using professional languages; using daily languages]?*	Q0.6

something like WhatsApp in healthcare: where is the value if you get your message on the next day? Why don't we go back to the age with post?" (Interviewee #34, associate chief neurologist).

Interviewees suggested that prompt responses in a health information system would reduce the cognitive load associated with unnecessary wait times. For example, Interviewee #46 (registered nurse) told us: *"I followed the instructions in our system for our [collaboration] process. If there is a delay because of the system, then I have to wait, and then the next colleague has to wait, and then the whole team. It's annoying. ... It's always beneficial if everything can be assigned as soon as possible so that we don't have to waste our valuable time or make compromises just because of the IT system."*

Interviewees stressed that collaborative activities that are often based on exchange of data should even always be as close to real-time as possible. Interviewee #48 (head of a health IT consultancy) said: *"[For data exchange], would you say that quicker is better? For emergency situations you would say, 'Of course!' Otherwise you might say 'Not necessarily.' But the tricky part is that, as a whole, it [data exchange] is interlocking. Data go through the whole chain. The data you need right now might depend on the data from earlier steps or other collaborators. So the truth is that we always have to keep data exchange in real-time because the data might actually be needed in the next emergency situation*."

This category offers four questions to probe for concerns about system response times.

Category 4: Device Integration. This category concerns the variety of data-active devices that reduces collaborator's cognitive load (e.g., wearable sensors; smartphones; tablets; non-barrier devices), and the capabilities the system must afford to accommodate their use. Device Integration gives health IT users ubiquitous collaboration capabilities, as explained by Interviewee #34 (associate chief neurologist): *"I am usually involved in several medical cases at the same time. ... Our system was on my PC before. Then I had to go back to my office to check the system so that I would not miss states or instructions. I went to ward or emergency room, and then turned back to check my PC, again and again. ... Now that they gave me an iPad, its better, but still annoying, because I now have to carry so many things: medical devices, paper stuff, and so on. So I have to bring an intern to help me carry them. ... I told my hospital, I need a smart watch."*

Moreover, Device Integration allows health IT users to collaborate in an unobtrusive manner (e.g., data collection through wearable sensors instead of manual measuring or entering), as described by Interviewee #44 (health IT engineer): *"I see this as the future [of collaboration] from a data perspective. Because it's not just about an unobtrusive way to use IT, but also about giving people the possibility to automatically bring their own data into healthcare with sensors anytime, anywhere, without using cables. Such data are even more important than what you can collect in hospitals. ... Even at home we would have Wi-Fi to enable our patients to upload their daily data to a server or data center by using sensors, which was impossible or unimaginable before."*

This category contains four design questions that focus on enabling both manners with user devices.

Category 5: System Interoperability. Category 5 concerns the variety of internal and external information systems with which the collaboration system must interact at the time it is deployed and in the future, and the capabilities that the system must afford to accommodate those interactions. This category focuses designers on the capability of health information systems to interoperate with heterogeneous digital medical systems that are not necessarily built to common standards. Interviewee #36 (health IT researcher) said: *"In a perfect world, we would use the same standards everywhere [in healthcare], and people wouldn't have to worry about the interoperability problem, because we would always have a standard. ... In the real world different [healthcare] systems have different ways to exchange, which means you should also take those non-standard systems into consideration."*

We found that health information systems also have to pay attention to legacy tools or systems, including non-computerized paper-based tools. In healthcare, legacy tools in collaborative activities are still common, and cannot easily be replaced, as, for example, the story of Interviewee #37 (registered nurse): *"Our team also uses tools we invented ourselves. ... For the patient assignment, we use a whiteboard in our office. We just write down the names there, although we already have an IT system for that. It is because that our team leader is an old lady who learned the white-board approach from her leader, I don't know, 30 years ago. And she said, it's a best practice ... Once I asked my friend from another hospital; they have a similar situation! ... So, my point is that you just cannot ignore traditional tools. They have become integral part of our (collaboration) work."*

Design questions that belong to this category help designers identify system requirements that are relevant for system's interoperation with heterogeneous systems and different approaches.

Category 6: Process Adaptability. Process Adaptability concerns the variety of conditions under which people must collaborate to provide healthcare, and the capabilities the system must afford to accommodate that range of conditions. This category is relevant for two reasons. First, although the healthcare industry strives to define all conditions or situations for collaboration in an exhaustive manner, unpredictable occurrences and exceptions often appear (e.g., new variant of a certain disease/symptom for which pre-defined collaborative treatment process is not appropriate). Interviewee #30 (obstetrician) stated: *"People think that healthcare processes are very well defined, but it's not really the case because it's too difficult to completely define all of them. For our daily [collaboration] processes, we actually need ongoing improvement. … In my hospital, the IT department regularly asks for our feedback and refines the IT-supported [collaboration] processes. … It's great, but not great enough. Everyone thinks that we have already defined all possible situations clearly … So, they think that no matter what happens, there will always be a solution, a path for it. But it's not hundred percent. There are always exceptions that we never met before. So, IT is still not flexible enough, at least from the medical perspective. … It would be great if we can adjust the process a little bit on-the-fly."*

Second, even small adaptions of organizational policy or industrials regulations can affect the ways people collaborate in healthcare. Interviewee #37 (registered nurse) told us: *"Next year, we will change from four levels to five levels of nurses, because insurance companies want it. So, we have to reorganize some [collaboration] processes, which already happened last year."*

Interviewee #48 (head of a health IT consultancy) also stated: *"In the U.S., for example, you had Obama Care, then something (about the collaboration process) has to change. Several years later, the next president wants to eliminate it, and something (about the collaboration process) will have to change again."* By proposing five design questions in Table 1, Category 6 highlight relevant requirements that enable systems to adapt to changes or exceptions in collaboration in healthcare.

Category 7: User Awareness. User Awareness concerns the degree to which users can know: a) with whom they are collaborating (identities and roles); b) what each person is expected to do (rules about what each role should do under what constraints using what capabilities); c) what aspect of the system each person is currently in; d) what each person is doing; e) who executed each action; f) the current states of activities; and g) the current states of the environment. This category not only aims at increasing a collaborator's understanding of his/her own role, rules, tasks, and responsibilities, but also at increasing collaborator's cognitive transparency of the whole collaboration environment. Interviewee #27 (gynecologist) stated: *"When a patient is in our hospital, what stage he is currently in is very, very important for the next department that will receive him to know these things … for example, to manage the bed situation, availability of doctors and nurses, and so on. This would provide buffer time for us, and increase the efficiency of coordinating the team."*

Interviewees further argued that increased transparency improves collaboration in healthcare from the medical data perspective: *"There is an IT platform for patient data exchange in Austria; it is a centralized electronic patient record system. … The patient has to define and decide, what doctors have what kinds of access to what part of my data. The data will not only be shared, but also be withdrawn, if something changes. Of course, we are also talking a bit about the topic data privacy, but I see this topic more as transparency. And I believe that transparency has to be the pre-condition if data exchange can be realized at all in healthcare. So, we have to use a high art to design our system so that it can support this transparency. … Increasing user awareness could act as such a high art to dynamically inform users about everything in their environment that is important to them, and to calm them down. … This is a kind of guarantee that the whole [collaboration] based on data exchange would work."* (Interviewee #48, head of a health IT consultancy).

Design questions in this category especially focus on what different (kinds of) information is (are) needed to increase User Awareness.

Category 8: (Patient) Data Integration. This category concerns the variety of sources from which the most relevant data for collaboration in healthcare must be gathered, the completeness of data, and the capabilities the system must afford to integrate those sources. In healthcare, patient data are the most essential data for collaborative activities. Patient data are often decentralized and fragmented, and have therefore sometimes limited availability (e.g., [21]). Interviewee #38 (health IT researcher) stated: *"Without patient data, cooperation in healthcare, which is always about patients, is impossible or limited"*. Interviewee #33 (ophthalmologist) explained that: *"It's always necessary to collect all relevant data about a patient. … Every time a case is transferred to me, or I have to treat a patient together with other doctors, I not only care about the current medical data of the patient, but all other data related to his health. These are the knowledge base I need so I can cooperate with anybody … I am an eye doctor but I also want to know about patient's other detailed information, like when was her last period or has the* *patient ever paid for sex. … Patient data are often not complete. Maybe they have been collected, but I don't know where they are. So, I have to collect them again … In the end, data are description of a patient, like a specification or manual for him: the more detailed the better. Also, if I transfer data to another doctor, I am sure he prefers the detailed manual, not just a part of it".*

Design questions in Category 8 aim to identify relevant system requirements that increase the completeness of patient.

Category 9: Richness of System Cues. Category 9 concerns the variety of media richness associated with the information cues the system provides to users (e.g., explanations, patient records, human communication), and the capabilities the system must afford to present that variety. This category suggests designers to leverage media richness to help users understand (medical) data during collaboration in healthcare in a more effective manner and reduce users' cognitive load. This is because abstract information and/or data exist in healthcare that can be hard to interpret without assistance. Interviewee #42 (principal director of health IT consulting) gave an example: *"My mother is 82 years old and she went to see doctor. It took two hours for the doctor to finally understand where the problem was. So, this is actually one of the biggest challenges in healthcare collaboration. … Without using, for example, video technologies, it is difficult to use normal language to express everything. … let's be more innovative, you can build a model of human body, with which you can show where exactly the problem is or simulate what movement would cause what hurt. … It's much more intuitive than organizing language, and for understanding also, because you can just show it."*

Interviewee #31 (orthopedist in charge) explained how media richness could help collaborators reduce their cognitive load: *"Pictures and texts are not enough. Before, we had to use a series of pictures for the movement of a joint, for example. It was like you read these pictures and used your brain to image the movement, like lantern slides. It was tiring. … I also had to use text to describe everything to let others know what I did and found, which took a lot of time and nerves. … Now, you can shoot videos or create animation stead of writing text description. People can see what it actually was. It's straightforward."*

Design questions in this category do not only address what forms of information/data can be applied but also what human senses should be used to increase Richness of System Cues.

Category 10: Concept Clarity. Concept Clarity concerns the variety of concepts - medical and otherwise - that people must understand for successful collaboration in healthcare, and the capabilities the system must afford to assure that people gain shared understanding of those concepts. As pointed out by the interviewees, collaborators in healthcare do not necessarily possess sufficient knowledge that enable them to fully understand medical information or data (e.g., patients). Even for collaborators with medical background, assistance by the system can help them understand external information or data more precisely and thereby avoid misunderstanding. For example, Interviewee #27 (gynecologist) stated: *"In healthcare, data are sometimes not easy to understand because there are too many different organizations. Different hospitals could have different interpretations of the same concept. That's why we do not really take over all information for certain [medical examination] items, because some other small hospitals have their own interpretation, which is totally wrong. … I also had a patient who did some examinations in a foreign country. The results were in English. People there used abbreviations that I never saw, and I had to guess. … Sometimes also for a doctor from another area, he would not understand terms in my data or the meaning of them. I think you should try to describe or specify your data to the greatest extent so that people will have a consistent understanding."*

Design questions in this category assist designers to identify what information/data, and how they should be defined or clarified for collaborators.

4. Discussion

4.1 Implications

The typology of categories and design questions can be used to direct stakeholder attention to MO-MS collaboration-related requirements that they might otherwise overlook. Category 0, however, is a meta-category; the other ten categories elaborate one or more of the Category 0 concerns. The last column of Table 1 links the design questions from Categories 1 to 10 to the universal design concerns in Category 0. For example, Q3.4 (i.e., 'How should collaborators act if the prescribed minimum event latency cannot be maintained?') is associated with Q0.7 (i.e. 'What must collaborators say and do with the affordances to instantiate each procedure?'). Design question Q3.4 both addresses a specific topic for IT-supported MO-MS collaboration (i.e., Response Time) but is rooted in the more general SLMC (i.e., through Q0.7).

Based on these relationships, we recommend system designers to apply the proposed design concerns and design questions in two different manners. System designers who aim to implement a new system that supports MO-MS collaboration could start with design questions in Category 0 that represents the more general SLMC. For each design question enumerated in Category 0, system designers can further investigate its related design questions in Category 1 to 10 (e.g., for Q0.1: Q1.1, Q2.1, and Q10.3) to get more deepened and specified understanding of this design question coming from Category 0. Because SLMC provides a holistic view on designing collaboration systems, system designers are thereby able to address related system requirements for collaboration in healthcare in a holistic manner. For system designers who aim to improve an existing system concerning a certain aspect, we suggest them to start with the proposed Category 1 to 10. System designers can use the proposed categories as a checklist to first identify the aspects they want to target on. By doing so, system designers can identify requirements that are relevant for the identified aspects in a more efficient manner.

4.2 Contributions

This paper contributes knowledge to both Collaboration Engineering and health IT. The proposed categories of design concerns and design questions deepen our understanding of the problem space and solution space for IT-supported MO-MS collaboration. The healthcare-specific probes (i.e., design questions and possible options) demonstrate how the typology can be adapted to a specific domain, which is a contribution to collaboration engineering, and provide a useful tool for health IT. We thereby demonstrate the utility of the proposed typology. Thus, this study fulfills the purpose of Design Science Research, which is to use scientific knowledge and methods to solving important classes of practical problems in the field [22].

This work also has practical implications. The categories and design questions (with possible options) also can serve as a ready-to-use tool for health IT designers, as explained in the previous sub-section. The proposed categories and design questions can for example also be used to derive criteria for the certification of health information systems concerning their quality of supporting collaboration in healthcare, or to structure medical education content for the topic 'collaboration'.

4.3 Limitations and Future Research

This research examined design concerns for MO-MS collaboration only in the context of collaborative healthcare. It may be possible to discover additional design concerns and or additional design questions by exploring further evidences in other MO-MS domains.

This study only examined MO-MS collaboration in Germany and China. More may be learned with explorations in other countries. This study also focused only on professional stakeholders – IT and healthcare experts. It could be useful to explore further with stakeholders who are not healthcare and IT professionals, e.g., insurance companies, patients, and their families.

For future research, it would also be useful to further explore the relationships among the proposed categories of design concerns. It seems likely there may be design concerns pertaining not to a given category, but to relationships among categories.

5. Conclusion

With this Exploratory study, we investigated design pertaining to large-scale IT-supported MO-MS collaboration. We derived a typology of design concerns and design questions that should be useful for improving MO-MS collaboration systems designs. We demonstrated that the generalizable typology could be elaborated with details of a specific MO-MS domain to foster more-complete requirements definition.

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