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Abstract:

In recent years, the term 'smartness' has entered widespread use in research and daily life. It has emerged with various applications of the Internet of Things, such as smart homes and smart factories. However, rapid technological development and careless use of the term mean that, in information systems (IS) research, a common understanding of smartness has not yet been established. And while it is recognized that smartness encompasses more than the use of impressive information technology applications, a unified conceptualization of how smartness is manifested in IS research is lacking. To this end, we conducted a structured literature review applying techniques from Grounded Theory. We found that smartness occurs through actions, in which smart things and individuals interact, process information, and make data-based decisions that are perceived as smart. Building on these findings, we propose the concept of a 'smart action' and derive a general definition of smartness. Our findings augment knowledge about how smartness is formed, offering a new perspective on smartness. The concept of a smart action unifies and increases understanding of 'smartness' in IS research. It supports further research by providing a concept for describing, analyzing, and designing smart actions, smart devices, and smart services.

Keywords: Smartness, Smart Action, Smart Thing, Internet of Things, Digital Technologies, Literature Review, Grounded Theory.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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This manuscript underwent [editorial/peer] review. It was received xx/xx/20xx and was with the authors for XX months for XX revisions. [firstname lastname] served as Associate Editor.] **or** The Associate Editor chose to remain anonymous.]

1 Introduction

The term 'smart' is widely used throughout academic literature, particularly in the context of the Internet of Things (IoT) and related application domains (e.g., smart home, smart city, and smart factory) (Porter & Heppelmann, 2015; Wiener et al., 2020). Yet, in the wake of recent technological developments and the inflationary use of the term, it remains unclear what is actually meant by 'smart' or 'smartness' (Alter, 2019). The terms also appear in other contexts and domains, such as in technical, economical, and social vocabulary (Gaztambide-Fernández & Rivière, 2019; Paukstadt & Becker, 2019; Thakor, 2015). In IS research, the term has become increasingly popular and important (Huber et al., 2019; Weber, 2017). Smartness appears in various contexts and forms, from descriptions of the intelligent use of resources (e.g., smart vehicle charging) (Brandt et al., 2017) to general characteristics (e.g., smart products, smart services) (Weber, 2017). In the IS literature, smartness is often connected to recent IoT-related technological (Velsberg et al., 2020) or socio-technical developments, building upon sensors, connectivity, information exchange, data processing, and capabilities for inferring and reasoning (Alt et al., 2019). For example, Beverungen et al. (2019) define smartness in the context of products – i.e., smart products – which they describe as being capable of exchanging data, processing information, and making autonomous decisions or physical actions.

Although the number of IS publications on smartness has vastly increased in recent years (Cheng & Liang, 2018; Lim & Maglio, 2018), understanding and descriptions of smart things, smart services, and smart systems vary significantly (Alter, 2019). For example, Beverungen et al. (2019) define smart products as boundary objects interacting between customers and service providers. In contrast, Oberländer et al. (2018) define smart things as physical objects equipped with their own agency and human-like cognitive characteristics. Similar to Oberländer et al. (2018), in the service literature, Lim and Maglio (2018) describe smart service systems (SSS) as capable of learning, dynamic adaptation, and decision-making. They attribute various characteristics to SSS, including self-X-capabilities and connections between things and people (Huber et al., 2019). Yet, they do not examine in detail the actions in which smart things take part or consider why such actions are perceived as smart (Peters et al., 2016). Hence, most definitions of smartness in the context of smart things that IS research currently offer are either highly domain-specific or very general. Among the most specific definitions relating to digital technologies (DTs), Alter (2019) claims a smart entity "[produces] useful results through activities that apply automated capabilities and […] resources for processing information, interpreting information, and/or learning from information" (p. 384). Alter's (2019) definition, which he synthesized based on his own experience and perceptions, leaves room for further specification. It also leads to questions: for example, is smartness to be found within the entity, the process, or perceived in results.

Yet, while IS research is rich in explorations of smart things, smart services, and their application domains, to the best of our knowledge, it offers no clear understanding of the concept of smartness. There is significant literature on smartness as a characteristic, but research lacks a well-grounded understanding of smartness in the context of its formation, manifestations, and actors. So far, no study has examined the state of research on smartness and its application fields in different domains to analyze the common understanding of smartness. This lack of knowledge hampers scientific progress as well as clear-headed decision-making in industry. The successful integration of smartness in products and services depends on establishing useful and goal-oriented interactions between smart things and their environment. Predicting whether an adoption takes place successfully or unsuccessfully (e.g., a smart waste management system in Torkayesh et al. (2021) or smart buildings in Thieme (2020)) requires a holistic understanding of the phenomenon. This includes, in particular, knowledge of the various actors involved in such interactions and of how they are linked to one another. The implementation project of the smart waste management system, for example, requires an understanding of the interactions among citizens and smart bins to ensure that the smart bins are successfully adopted by the citizens (Torkayesh et al., 2021). Furthermore, practitioners need a conceptual understanding of the socio-technical interactions into which smart things are involved. They need to assess which impact smart things will have on customers and how customers can interact with them. On this base, practitioners can assess better how they should design smart things to offer the most value for customers, while researchers can develop more comprehensive design theories and design principles for smart things. Hence, both research and practice benefit from a conceptual understanding of smartness as a foundation for the successful design of smart things. Correspondingly, our study intends to fill this gap by answering the following research question: How is smartness manifested in IS research? We contribute to IS research by conceptualizing smartness to describe the actions that take place when something is perceived as smart. Future research can build upon this concept with a clear idea of the manifestation of smartness in IS.

To understand smartness in IS literature, we conducted a structured literature review identifying and connecting concepts linked to smartness that repeatedly appear in IS research. We followed the approach proposed by Wolfswinkel et al. (2013) to conceptualize smartness by using and combining Grounded Theory (GT) techniques based on a structured literature review. Thereby, we aimed to develop a thorough and well-grounded analysis of smartness in IS revealing connections between related concepts and developing a clear concept of smartness. We decided to leverage GT because we found that there were no extant theories to explain how smartness takes place in IS research. The building of theory using GT is based on a structured analysis of empirical data, which leads to a theorization to describe an observed phenomenon (Dey, 1999). The result is a theory that has not been derived from existing conceptual frameworks, but is grounded in evidence (Gasson & Waters, 2013). Our decision to apply GT was also driven by the need to understand the processes that take place when smart things interact with users or other smart things. GT provides an effective method to generate process theories (Charmaz, 2000). As GT is an inductive research approach, it allows for an open-minded exploration of a phenomenon as well as for the emergence of meaningful concepts (Birks et al., 2013). Our discovery that smartness becomes manifest through smart actions led us to explicate active and passive actors. Aiming to understand smartness, we describe how these actors and components interact. We contribute to IS research by synthesizing widespread insights about smartness which we assemble into an overall picture.

The remainder of this paper is structured as follows: In the next section, we examine the theoretical works on smartness, definitions, and domains of application. The third section provides a detailed account of our research method, including the application of GT techniques with reference to our literature review. The fourth section presents our concept of smart action. We then discuss the contribution of our concept, its limitations, and how future research should proceed. Finally, we conclude by summarizing the most important aspects of our study.

2 Theoretical Background

The term 'smart' is nowadays widely used in social as well as business contexts. Suppose you search for this term in dictionaries. In that case, definitions such as "the quality of being intelligent, or able to think quickly or intelligently in difficult situations" (Cambridge Dictionary, 2021) or synonyms such as "intelligence, brightness, wisdom" (Mariam Webster Dictionary, 2021) can be found. Most definitions and descriptions understand smartness as a human characteristic. However, this characteristic is also applied in other contexts and can be found in other research disciplines. For example, in biology, smartness in the broadest sense refers to the ability of an organism to adapt to its environment through learning and through shaping the environment by employing the organism's cognitive abilities (Cianciolo & Sternberg, 2011; Stanovich, 2009). Whereas an animal's intelligence can be defined and measured by the speed and success of solving a problem to survive in nature (e.g., problems related to feeding) (Sternberg, 2020), the characteristic involves much more for humans. Research on smartness in psychology focuses on aspects such as rational decision-making, creative thinking, and wisdom to achieve a personal or externally set goal beyond the inherited biological goals of survival and success of reproduction (Matthews et al., 2004; Stanovich, 2009). Although various definitions and understandings of smartness exist across disciplines, there is no universally accepted definition.

Besides research in medical or social domains, smartness has been used increasingly often in a technical context, particularly for DTs shaping our daily routines. Similar to the human capability of being smart, a DT's smartness does not relate to survival and success of reproduction but to rational decision-making and the recognition of logical connections. In IS research, the term is often connected to digital capabilities embedded in physical objects to enable human (i.e., rational) capabilities such as reactivity, adaptability, and autonomy (Benbya et al., 2020; National Science Foundation, 2016; Novales et al., 2016). For example, today's homes can be equipped with smart devices capable of managing the household and performing tasks such as controlling the fridge (Borgia, 2014; Solaimani et al., 2013). In short, smart devices and systems can now carry out actions, functions, or services of which only humans were previously capable (Fleisch & Thiesse, 2007; Huber et al., 2019). This is why 'smart,' as a characteristic, is often used to express the ability of devices to make decisions using contextual information, thus, mimicking properties of human intelligence (Alter, 2019; Gavrilova & Kokoulina, 2015). This technological development provides a foundation for new services and business models, and further academic inquiry is required to explore its full potential. In the following, we reflect on current research and introduce concepts related to smartness in the IS domain. These concepts serve as a foundation for our conceptualization of smartness.

2.1 Digital Technologies and the IoT

DTs are central understanding and a vital building block for creating smartness (i.e., developing smart actions) in the IS domain (Berger et al., 2018). Benbya et al. (2020) characterize DTs as objects that induce complexity through embedded digital capabilities (e.g., being editable or reprogrammable) to encode and automate complex and abstract cognitive processes. Such capabilities enable DTs to adapt to changing contexts and environments (Yoo, 2010). DTs often possess the capability to connect to and communicate with other DTs or individuals, forming webs of socio-technical relations and, thereby, building a digital infrastructure (Benbya et al., 2020; Reuver et al., 2018). A more general definition describes DTs as "combinations of information, computing, communication, and connectivity" (Bharadwaj et al., 2013, p. 471). Initially subsumed as SMACIT technologies (i.e., social, mobile, analytical, cloud-based, IoT) (Vial, 2019), they have become the base for further technological developments such as those referred to by the DARQ acronym: distributed ledgers, artificial intelligence (AI), extended reality, and quantum computing (Daugherty, 2019). It is worth noting that some DTs – such as platforms, digital agents, or analytical technologies – exist only in the digital world (Runde & Faulkner, 2019; Vial, 2019). Although these DTs may have some form of physical representation, they are characterized by a passive form of usage in which the DT remains largely invisible for users and has no direct impact on its physical environment (Berger et al., 2018).

By nature, DTs obtain an entity in the physical and the digital world simultaneously (Benbya et al., 2020; Berger et al., 2018). The connection of DTs embedded in physical objects is referred to as the IoT, "the connectivity of physical objects equipped with sensors and actuators to the Internet via data communication technology" (Oberländer et al., 2018, p. 488). DTs bridge the gap between the physical and the digital world and are, in the context of smartness, commonly referred to as 'smart things,' 'smart devices,' or 'smart products' (Beverungen et al., 2019; Oberländer et al., 2018). Since the characteristics of the terms 'smart things', 'smart devices' and 'smart products' largely coincide, we use the term smart things in the following. Even though DTs without a physical core occasionally appear in IS literature, primarily in the context of smartness – e.g., AI-based approaches to make sense of data or derive decisions (Alter, 2019) – IS research focuses chiefly on smartness in relation to smart things (Fernando et al., 2016; Warkentin et al., 2017; Weber, 2017). Therefore, in our analysis of smartness, we focus on smartness in the context of smart things.

2.2 Smart Things as Vital Building Blocks of Smartness

In their most basic form, smart things can perceive, share, and receive information from other devices (Nicolescu et al., 2018). By collecting data (e.g., of their environment or usage) and exercising self-controlling capabilities, often referred to as self-X properties, smart things can autonomously adapt to their environment (Püschel et al., 2020; Raman & McClelland, 2019). Thus, new interactions between smart things, individuals, and organizations emerge. Beverungen et al. (2019), for example, provide a conceptualization to define and describe smart products as boundary objects communicating between service consumers and service providers. They further summarize the core properties of smart products, including unique identification, localizing, and connectivity. Accordingly, smart things are identifiable resources that can be referenced to a unique product and integrated with resources at remote locations via connectivity. Other core properties are sensors, storage and computation, actuators, interfaces, and invisible computers (Beverungen et al., 2019). The embedding of sensors, actuators, and communication technology into physical objects further leverages the emergence of new functions and services (Oberländer et al., 2018). In the literature produced over the past few years, two research streams have begun to dominate how we think about smart things. One school of thought considers smartness to be a characteristic of data-based actions (e.g., dynamic adaptation, learning, and decision making) carried out by smart things. Meanwhile, the other school of thought focuses on the mediating role that smart things play in the interaction of service providers and service consumers (Huber et al., 2019). While it is useful to note that smartness plays a major role in service science, our focus is on smartness at the level of smart things and their ability to carry out actions. According to the former research stream, data-based capabilities empower smart things to perform actions that are perceived as smart. Such actions build upon the availability of as yet inaccessible data, data analysis, and autonomous decision-making capabilities (Leonardi, 2013; National Science Foundation, 2016; Porter & Heppelmann, 2014). Alter (2019) defines smartness as possessing four characteristics: *information processing*, *internal regulation*, *actions in the* *world*, and *knowledge acquisition*. These characteristics are of considerable help in describing and categorizing different perspectives on smartness and are, consequently, major research streams in the literature.

3 Research Method

In seeking to produce theoretical analysis and a description of real-world phenomena, it is useful to look at concepts and their underlying constructs as a way to describe theoretical knowledge (March & Smith, 1995). Exploring concepts and building a generic concept is a well-established approach to synthesize and extend existing research (Dernbecher & Beck, 2017; Peppard, 2018; Webster & Watson, 2002). In this study, we investigate smartness in IS using a theory of analysis and description which focuses on the relationships between particular concepts (Gregor, 2006). A methodological approach for systematically deriving such a theory is GT, which involves the construction of theories through methodically gathering and analyzing data (Glaser et al., 1968; Strauss & Corbin, 1990). GT allows for the inductive discovery of a theory (Wiesche et al., 2017). In this way, GT enabled us to develop a detailed theoretical understanding of the phenomenon under investigation while also grounding the representation in empirical data (Strauss & Corbin, 1990).

Based on the literature reviews by Webster and Watson (2002), GT has been applied by Wolfswinkel et al. (2013) in peer-reviewed publications in domain-specific journals as well as conference proceedings for inducing theory (Boell & Cecez-Kecmanovic, 2015). GT derived from literature is theory-based and concept-centric, and as such it enables researchers to attain a high degree of accuracy (Wolfswinkel et al., 2013). The value of reviewing literature to derive GT lies in the structured analysis of textual data (Schultze, 2015). Ideas emerge and connect with different concepts in a way that allows us to appreciate their roots, interrelationships, and co-dependencies within a particular area, while also pointing us beyond these to the discovery of new issues (Webster & Watson, 2002; Wolfswinkel et al., 2013). With these benefits in mind, we used GT as the research methodology for this study, as smartness is a widely discussed topic in IS literature.

Below, we discuss the application of the approach proposed by Wolfswinkel et al. (2013), which consists of five steps: “Define”, “Search”, “Select”, “Analyze”, and “Present” (illustrated in Figure 1). In the “Define” step, researchers define inclusion and exclusion criteria before identifying the research domains, appropriate sources of evidence, and the search terms. The “Search” step involves applying the search term and the inclusion and exclusion criteria to data sources. In the “Selection” step, authors refine the sample and reduce the number of papers for analysis. Finally, the “Present” step involves representing and structuring the content and structuring the article (Wolfswinkel et al., 2013). While we discuss the first four steps in detail, we do not elaborate on the final step which only concerns the distribution of research in the community.

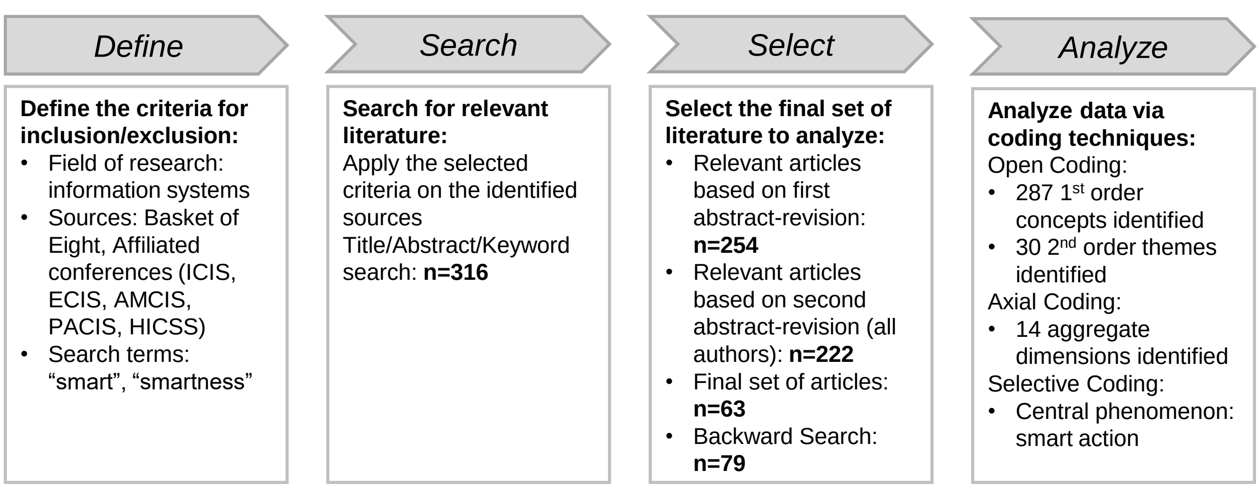


Figure 1. GT Approach (Source: Wolfswinkel et al., 2013)

3.1 Define and Search

Since our goal was to conceptualize how smartness is manifested in IS research, we only examined literature published in the IS domain. To ensure that our conceptual base consists of high-quality research, we searched for literature in the Senior Scholars Basket[1]. Due to the topicality of the research theme, we added the *International Conference on Information Systems* and the *European Conference on Information Systems*, which are part of a selection of journals and conferences proposed by the Association for Information Systems (AIS) Community (Bandara et al., 2015). To ensure our review reflected current research, we also included the recent *Americas Conference on Information Systems*, *Hawaii International Conference on System Sciences*, *and Pacific Asia Conference on Information Systems*. Smartness is a research topic that affects various domains such as, for example, manufacturing, energy, or the public sector. As IS research involves many interdisciplinary research papers, we refrained from additionally searching for literature in those specific domains. Exemplary, public-sector journals (such as Government Information Quarterly) published many smartness-related papers, especially related to smart cities. As our literature sample also covers nine studies about smart cities (e.g., Petercsak et al., 2016; Marinovici et al., 2017), we did not additionally include public sector journals. Next, we selected appropriate search terms (Vom Brocke et al., 2015; Webster & Watson, 2002; Wolfswinkel et al., 2013). Beneath the terms “smart” OR “smartness” that were central to our research question, we also tried to include synonyms, what resulted in a wide range of papers. For example, including the synonym “intelligent” brought more than 11,000 papers. After reviewing a random sample of these studies, we confirmed that few were relevant to our research. Consequently, we searched for “smart” and “smartness” and limited the appearance of the search terms to title, abstract, and keywords to receive a pre-filtered sample suitable for a structured review (Vom Brocke et al., 2015). This search brought 316 papers that met our inclusion criteria (i.e., smart or smartness).

3.2 Select

To determine the relevance of the selected studies, we screened titles and abstracts to obtain a more detailed overview of the papers (Bandara et al., 2015; Vom Brocke et al., 2015; Webster & Watson, 2002). To do so, we used a four-point Likert scale and assigned each article a score. Introducing the following clearly defined parameters ensured that all authors assessed the papers using the same criteria. 4 – the article mentioned search-terms “smart” or “smartness” in a context that had no connection to the research question. We excluded papers that only contained the search terms within the references or as an expression that did not refer to the underlying concepts, e.g., ‘‘organizations should take smart decisions...’’. 3 – this criterion comprised papers that mentioned the search terms without a clear focus on smartness and its underlying actors. Articles that primarily dealt with the technical implementation of software, methods, and algorithms (e.g., Shamoug & Juric, 2017), or with the development of concepts that were too far away from the technology in focus. Koslowski et al. (2013), for example, deals with smart grids but is mainly focused on developing a teaching concept for Green IS education. 2 – the use of the search-terms had a connection to the research question. This criterion included papers whose abstracts indicated a focus on smartness in the context of smart things and interactions between smart things and other actors. It included any form of usage of smart things or integration of smart things into systems, such as integration of a smart home application into a resident’s house (e.g., in Kuebel and Zarnekow (2015). 1 – the keywords appeared clearly in the context of smart things and its use as well as application in different contexts. 1 encompassed papers with abstracts that clearly stressed the focus on smart things involved in interactions and engaging with its environment, such as in Püschel et al. (2016), who describe interaction capabilities of smart things. In total, of the 316 articles extracted from IS literature, 62 (19.6%) scored “four”, 68 (21.6%) scored “three”, 119 (37.6%) scored “two”, and 67 (21.2%) scored “one”. All authors reviewed the abstracts and parts of the content of articles scoring “three” and either upgraded them to “two” or downgraded them to “four” to ensure that no relevant study was excluded. We upgraded 36 articles to the score “two” and downgraded 32 articles to “four”. We then removed 21 papers that were ranked with “two” but mentioned the search terms “smart” or “smartness” only 3 times or less in the whole study (Dernbecher & Beck, 2017), leaving 134 consolidated and affirmed studies with a “two” rating, which we added to the list of papers to be read in-depth. Conducting a full-text analysis of the final set of 201 papers, we read all papers completely and extracted relevant insights connected to smartness. In this

[1] The basket includes the journals *European Journal of Information Systems*, *Journal of Information Technology*, *Information Systems Research*, *Information Systems Journal*, *Journal of the Association for Information Systems*, *Journal of Management Information Systems*, *Management Information Systems Quarterly*, and *Journal of Strategic Information Systems* (AIS, 2011).

step, we narrowed down the analyzed set of 201 papers to 63 papers as the excluded papers showed no relevant contributions to our research question and we could not extract valuable insights from them on smartness in IS. Table 1 demonstrates how many papers we extracted from each outlet. We further added 16 papers through backward search. Appendix B provides a complete reference list of all 79 papers included in the literature sample.

Table 1. Overview of How Many Papers Per Outlet

Journal	Number of Publications
European Journal of Information Systems	4
Journal of Information Technology	3
Information Systems Research	2
Information Systems Journal	1
Journal of the Association for Information Systems	3
Journal of Management Information Systems	2
Management Information Systems Quarterly	5
Journal of Strategic Information Systems	3
International Conference on Information Systems	9
European Conference on Information Systems	12
Americas Conference on Information Systems	9
Hawaii International Conference on System Sciences	7
Pacific Asia Conference on Information Systems	3

3.3 Analyze

To analyze the identified literature, we applied three steps of coding: *open coding*, *axial coding*, *and selective coding* (Strauss & Corbin, 1990; Wolfswinkel et al., 2013). Coding (i.e., the extraction of important findings and statements) is an essential part of GT based techniques to unbiasedly extract relevant knowledge from the literature of a certain topic (Wolfswinkel et al., 2013). Throughout open coding and axial coding, we additionally followed the recommendations of Gioia et al. (2013) on qualitative data analysis in order to adapt a more systematic approach in developing concepts and articulating theory, strengthening the rigor of our research. The Gioia et al. (2013) approach is well-established for qualitative data analysis and has often been applied in in IS research (Hübner et al., 2016; Li et al., 2018). It is an expansion of the GT approach of Strauss and Corbin (1990) on how to structure and visualize data while referring to analogies with open and axial coding. Gioia et al. (2013) divide the outcomes of the data analysis procedure into three steps. At the beginning, similar to open coding, 1st order concepts are distilled and synthesized from the data. Like axial coding, 2nd order themes are the result of a further grouping of the 1st order concepts and first theorizations to describe and explain the phenomenon. In the third step, the 2nd order themes emerge into aggregate dimensions and result in the last concepts necessary to describe and explain the phenomenon under investigation.

First, during *open coding*, researchers identify all concepts relevant to a research question resulting in 1st order concepts. The 1st order concepts are then grouped and assigned to 2nd order themes (Gioia et al., 2013). Appendix C shows part of the data structure. For open coding, we first carefully read the identified literature and highlighted any findings that were relevant for smartness. Based on these findings, we assigned the identified codes to 1st order concepts and 2nd order themes (Gioia et al., 2013; Wolfswinkel et al., 2013). This set was continually revised to include new findings and exclude concepts that appeared not to be representative for smartness as the data analysis progressed (Yang & Tate, 2012). This process ended in the first abstraction of the examined studies, where we identified 287 1st order concepts, which we further grouped into 30 2nd order themes (such as “Acting Smart Thing”, “Acted-Upon Smart Thing”, “Acting Individual” etc.). We show a graphical representation of a selected sample of 1st order concepts (only the first two 1st order concepts are shown to help readability) and 2nd order themes in Appendix C (Pratt, 2008; Tracy, 2010). Appendix C also includes aggregate dimensions which are the result of axial coding and which we describe in the following. Additionally, we provide the full database in Appendix D.

During *axial coding*, we further grouped the 2nd order themes in aggregate dimensions. After a workable set of 2nd order themes has been built, we started combining the related 2nd order themes into aggregate dimensions (Gioia et al., 2013). This step involved moving back and forth between the 2nd order themes and the literature and resulted in the identification of theoretical categories that did not have adequate representation in the extant literature on smartness (Gioia et al., 2013). The process of deriving the aggregate dimensions included summarizing congeneric 2nd order themes and abstracting them to a higher abstraction level, thereby identifying strong patterns that represent the use of smartness in IS research. By constantly comparing the summarized set of congeneric 2nd order themes to existing theoretical concepts from non-smartness literature, we identified the aggregate dimensions. For example, we identified a smart shirt that autonomously calls the hospital (Ma et al., 2017) (1st order concept) representing an acting smart thing (2nd order theme). Similarly, we identified a resident owner adjusting the temperature through a smart meter (Bomhard & Wörner, 2016) (1st order concept) where the resident owner is an acting individual (2nd order theme). In this case, we found two 2nd order themes whose core characteristic is an acting ability and who act upon others. Moving one abstraction level higher, we exerted that the core of the two 2nd order themes, which is the acting ability, is in line with the role of a subject as described in activity theory. Appendix E exemplarily shows the detailed process of how we derived the aggregate dimension “subject” from the literature. In the axial coding process, the 30 identified 2nd order themes including the underlying 1st order concepts and text excerpts were divided equally between three authors and were analyzed to identify related 2nd order themes. Next, we discussed and refined the separately identified 2nd order theme groups within the author team, resulting in the final 14 2nd order theme groups. These final groups were divided between the author team to build the aggregate dimensions and to find comparable theoretical concepts from other domains to enrich our findings with existing theory. Thereby, we found the three adjacent theories. The result of this process was again collectively discussed and refined within the author team, resulting in the final aggregate dimensions. The goal of this approach was to generate intensive group discussion and consensus, not to demonstrate inter-coder reliability (Berente et al., 2011; Saldana, 2009). After identifying the aggregate dimensions, the author team tried to identify relationships between the aggregate dimensions (Gioia et al., 2013; Strauss & Corbin, 1998). This process is called theoretical sensitivity as researchers discover relationships between aggregate dimensions that result in constructing a grounded theory relevant to the field under study (Glaser, 1978). To do so, we theorized and re-conceptualized the identified dimensions to the point that no more concepts, themes, or dimensions could be found in the literature sample. The achievement of this target state is referred to as theoretical saturation in GT (Strauss & Corbin, 1990). Axial coding resulted in further structuring our initial set of 30 2nd order themes into 14 aggregate dimensions (such as “Subject”, “Object”, “Tool”, and “Connectivity”).

Selective coding aims at proposing a central concept that represents and relates to all of the identified aggregate dimensions (Wolfswinkel et al., 2013). To describe the fundamental aspects of the central phenomenon (i.e., a smart action), we used the interrelations between the aggregate dimensions that we identified during the axial coding and constructed a central concept. We consolidated all 1st order concepts, 2nd order themes, and aggregate dimensions in the concept-matrix found in Appendix D. During the process of aggregate dimension building and theory building, we compared our theoretical findings with existing theories from (non-)IS specific domains and examined how these theories relate to and substantialize the concept development for smart actions. We asserted that the concepts identified in IS literature fit with three existing theories that researchers have already applied in the IS context. These theories – Activity Theory (Engeström, 1987), General Systems Theory (Bertalanffy, 1968), and Cognitive Information Processing Theory (Greifeneder et al., 2017) – enabled us to embed the inferred concept of a smart action within a well-established base of knowledge. By applying these GT-based techniques, in particular constant comparison (i.e., comparing identified concepts with additional data) and theoretical sensitivity (i.e., engaging the substantive theory with existing theories) (Urquhart, 2013), we complemented Wolfswinkel et al.’s (2013) GT approach.

4 Results and Analysis

4.1 Literature Analysis

We analyzed IS literature on smartness with the goal of identifying how smartness manifests in IS literature. Therefore, we conducted a GT approach, extracting 1st order concepts from literature, summarizing them to 2nd order themes and finally deriving aggregate dimensions. Within the process of identifying aggregate dimensions, we identified three overarching dimensions which are: action, system, and information processing. We identified these central themes based on repeatedly used terms, the type of technology and algorithms that were implemented in objects in the context of smartness, as well as based on the use of smartness-related technologies and the settings and contexts in which they were used. Screening the literature, we identified many papers that referred to the concept of acting when describing the use of smart things. Püschel et al. (2016), for example, develop a multilayer taxonomy of smart things where one layer called “thing layer” comprises “sensing and acting capabilities”. Oberländer et al. (2018), similarly, credit material agency to smart things and describe them as “independent actors”. This led us to the conclusion that smartness in IS literature, for a great part, appears in the context of actions and activities. We further analyzed those actions and derived six interaction patterns that form the core of the smart action. Another concept that repeatedly appeared in smartness literature was the concept of systems. Bomhard and Wörner (2016), for example, repeatedly used the term system when referring to the unity of a smart heating application and the residents of an apartment. Cu et al. (2017), on the other hand, described a smart irrigation application where the farmer, the farm, and the smart irrigation application built up a system that was triggered by environmental factors (e.g., rain, wind, etc.). Therefrom, we derived that the actions and activities in which smart things are involved take place within systems and must comprise several actors. Furthermore, we observed intertwined mechanisms with concepts outside the system. The type of information technology integrated into objects in the context of smartness usually comprised information-processing algorithms that process information as inputs and either take decisions themselves or provide decision templates for human beings. Corbett and Mellouli (2017), for example, described the use of smart things in a smart city context that captured critical data on water quality using “underwater sensors and cameras” and “triggered automated responses in case of critical incidents”. Such statements made us realize that smart things performed a recurrent pattern of information processing steps, beginning with perceiving some form of input and resulting in performing some form of response to the input.

In summary, when examining the smartness related IS literature, we found that smartness occurs in various manners and is described in diverse ways. However, smartness appears in similar patterns and involves the same types of actors (i.e., individuals, smart things) and components (i.e., physical objects, technologies, tools). These feature in publications relating to smart technologies (Ojo et al., 2014; Warkentin et al., 2017), smart systems (Busquets, 2010; Vervest et al., 2004), and smart systems of systems (Corbett & Mellouli, 2017; Petercsak et al., 2016; Porter & Heppelmann, 2014). The literature consistently suggests that smartness includes a reproducible set of actors, components, and the ways in which they interact. From these observations, we developed a way of describing how smartness appears in IS research, building a concept of the inner nature of smartness: a ‘smart action’. In the following, we provide an overview of the concept of a smart action and explicate its sub-concepts in detail.

4.2 Overview of Smart Action

4.2.1 Subject, Object, Tool, and Connectivity

An action, as commonly known, can be defined as the accomplishment of a human being or thing over a certain period of time or in different stages (Merriam Webster, 2021). Human beings and things act to solve problems or achieve certain outcomes (Igira, 2008). In the context of smart things, action denotes the physical representation of smart things and their impact on the stakeholders, including sensing, actuation, coordination, communication, and control (Beverungen et al., 2019; Oberländer et al., 2018). As a result of our literature review, we found that smartness manifests in a smart action that includes interactions between, smart things, individuals, and physical objects. In the following, we will describe the interactions that form the smart action in detail.

To determine which actors and components are involved in smart actions, we examined and coded the literature sample. The so-identified subjects, objects, tools, and their connectivity can be described by their 2nd order themes, which we, again, explain below. Between these, different interactions occur, usually involving subjects carrying out actions upon objects (Figure 2) (Benbunan-Fich, 2019; Niemimaa, 2016).

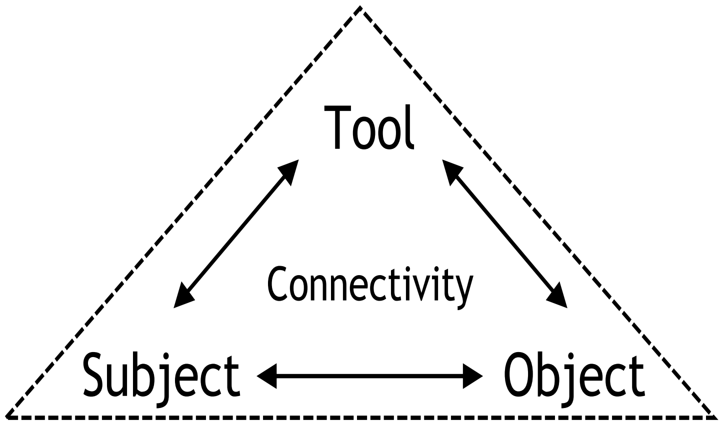


Figure 2. Subject-Object-Interactions

Subjects can either be *acting individuals* (i.e., human beings) or *acting smart things*. By "acting", we refer to individuals or smart things that act upon an object or themselves and, thereby, play an active role in an activity. Smart things are physical technologies with computing logic, sensors, actuators, and connectivity (Oberländer et al., 2018). Through these components, a smart thing becomes capable of observing its environment, connecting to other actors (e.g. technologies) as well as service systems (thus, forming systems of systems), and acting upon others (Corbett & Mellouli, 2017; Novales et al., 2016). By combining capabilities for communication, sensing, and data analysis, smart things can process data and make decisions based upon the results (Püschel et al., 2016), something of which only humans were previously capable, fusing the physical and the digital world (Oberländer et al., 2018). 'Smart shirts', for example, are equipped with sensors and communication technology and can track an individual's heart rate, transmit the data to the individual's smartphone, and can even autonomously contact the hospital in case of critical heart rate (Ma et al., 2017). Different forms of acting capabilities are discussed in the literature, ranging from the ability to serve as an information provider (Warkentin et al., 2017) to carrying out actions autonomously (Brandt et al., 2017). Our findings show that the boundaries between actors – solely consisting of individuals – and components, tools, or technologies – solely serving individuals – have blurred.

Objects can be *acted-upon smart things*, *acted-upon individuals*, or *acted-upon physical objects*. As opposed to acting individuals and smart things, both can also play the passive role in an activity, thus becoming acted-upon individuals and smart things. *Physical objects* do not possess information technology (IT) that enables them to perform self-dependent actions (Slavova & Constantinides, 2017). The object is the motive of the action and is acted upon, either directly or indirectly, using a *tool* (Wickramasinghe & Haddad, 2017).

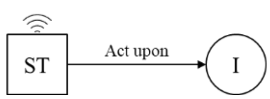
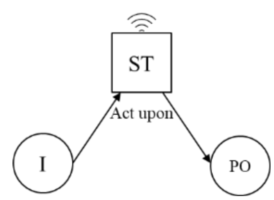
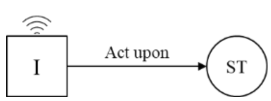
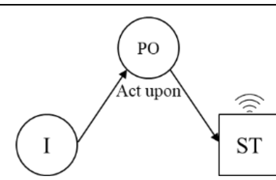
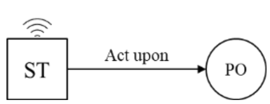
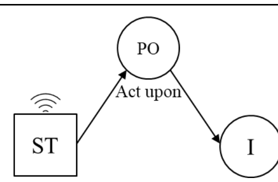
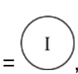
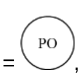
A *tool* is an intermediary artifact that enables the subject to act upon the object. In our literature review, we identified *intermediate smart things* and *intermediate physical objects* as tools. Bomhard and Wörner (2016), for example, describe a smart heating system, which can be controlled via a mobile phone and be adapted to individual preferences. Thereby, the mobile phone only serves as an intermediary artifact for the resident to control temperature and humidity. Subjects do something smart and, thereby, the smart action is initiated. As opposed to physical things, which can only be an object or a tool, smart things and individuals can be both an object and a subject at the same time. A smart thermostat, for example, can configure itself by adjusting its temperature (Oberländer et al., 2018). To enable interactions among subjects and objects, *connectivity* – the process of connecting two or more actors – is at the heart of Figure 2. Connectivity enables the exchange of information between previously disconnected subjects and objects, and is key for enabling smart actions (Hung et al., 2016; Novales et al., 2016).

Having introduced the different 2nd order concepts that we identified from the literature review and the aggregate dimensions that we grouped them into, we now present interaction patterns that these concepts take part in. One or more of these interaction patterns form the smart action. As we identified smart things, individuals, and physical objects in smartness related literature, we analyzed the relation between them when interactions take place. We draw from activity theory when analyzing the interactions among them. Activity theory formalizes the interaction of a subject with an object through the use of tools. In the theory, the subject is an acting human being that affects the object through an action (Benbunan-Fich, 2019).

Ultimately, the object represents the motive for the action of a subject (Kaptelinin, 2005). The tool serves as an intermediating artifact that contributes to accomplishing the intended goal of a goal-directed subject and can be of either physical nature (such as physical objects or technology) or psychological nature (such as language or symbols) (Allen et al., 2013; Karanasios & Allen, 2014).

In line with activity theory, we found different interaction patterns where different 2nd order concepts take over the role of subjects, objects, and tools. In the Smart Thing to Individual (ST2I) pattern, the smart thing is the subject and acts upon an individual. Smart shirts for example act upon an individual (i.e., patient) by tracking its heart rate data (Ma et al., 2017). In the Individual to Smart Thing (I2ST) pattern, an individual is the subject and acts upon a smart thing. An individual could, for example, exchange a broken component of a smart dishwasher (van Putten et al., 2011). One could ask if this pattern is really part of a smart action if the smart thing does not act or do anything smart. However, this pattern cannot solely be a smart action but can be part of a smart action in combination with other patterns. For example, prior to the exchange of the broken component, the smart dishwasher could have recognized the broken component via integrated sensors and notified the owner via a mobile phone (i.e., mediated ST2I pattern). The Smart Thing to Physical Object (ST2PO) pattern describes a smart thing being the acting subject and acting upon a physical object while the human being does only profit from this interaction without being actively part of it. A smart charging system (i.e., subject) can charge a vehicle (i.e., object) in a smart way by charging it when electricity is cheap (Brandt et al., 2017). The owner of the vehicle is not part of the interaction but profits from the cheap charging. The mediated I2ST pattern focuses on an individual as a subject that acts upon a smart thing using a physical object as a mediating tool to fulfil the action. An individual can, for example, use a chip card (i.e., physical object) to gain access to a smart health monitoring system in a hospital (Howell et al., 2016). In the mediated I2PO pattern, an individual (i.e., subject) acts upon a physical object using a smart thing as a mediating tool. For example, an individual can monitor the irrigation of an agricultural field through an application connected to a smart irrigation system. The smart irrigation system serves as the mediator that enables the irrigation monitoring while the individual performs the action (i.e., monitoring the irrigation) (Cu et al., 2017). Table 2 shows an overview of all six identified smart action patterns.

Table 2. Smart Action Patterns

Interaction Pattern	Name, Characteristics	Interaction Pattern	Name, Characteristics
	Pattern I (ST2I) Subject: Smart Thing Object: Individual Tool: -		Pattern IV (Mediated I2PO) Subject: Individual Object: Physical Object Tool: Smart Thing
	Pattern II (I2ST) Subject: Individual Object: Smart Thing Tool: -		Pattern V (Mediated I2ST) Subject: Individual Object: Smart Thing Tool: Physical Object
	Pattern III (ST2PO) Subject: Individual Object: Physical Object Tool: Smart Thing		Pattern VI (Mediated ST2I) Subject: Smart Thing Object: Individual Tool: Physical Object
Note: Smart Thing = , Individual = , Physical Object = , Interaction = →			

The smart action, as we understand it, is characterized by including one or more interaction patterns. The smart action can consist of only one one-directional interaction that includes one subject (e.g., smart thing) performing an action upon one object (e.g., individual). However, the smart action can also include multiple interactions performed after one another (see Figure 3 and Figure 4). The smart irrigation system (Cu et al., 2017) can, for example, first act upon an individual by providing information and recommendations on the irrigation amount (i.e., ST2I pattern). Then, in a second interaction, the individual adjusts the irrigation amount via the smart irrigation system based on the provided information (i.e., mediated I2PO pattern) (see Figure 3). Another example for a smart action including multiple interaction patterns is the smart shirt (Ma et al., 2017). Here, the smart shirt acts as a subject upon the individual by measuring its heart rate data (i.e., ST2I pattern). The smart shirt then initiates a call to the hospital doctor (i.e., object) in case of critical heart rate data via the patients' mobile phone (i.e., tool). This interaction is a mediated ST2I pattern (see Figure 4).

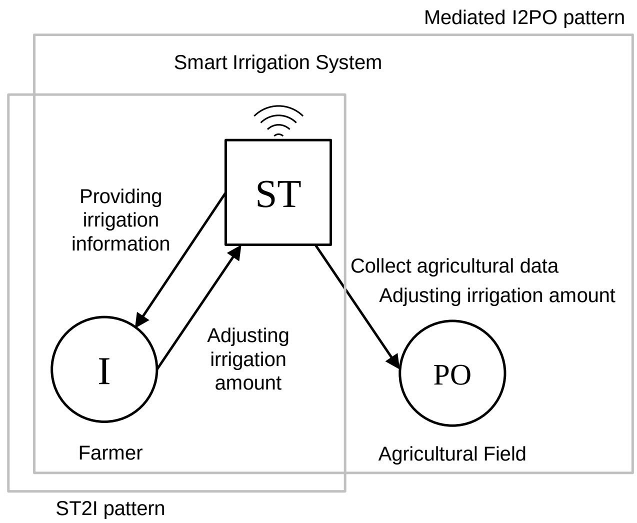


Figure 3. Smart Action of the Smart Irrigation System

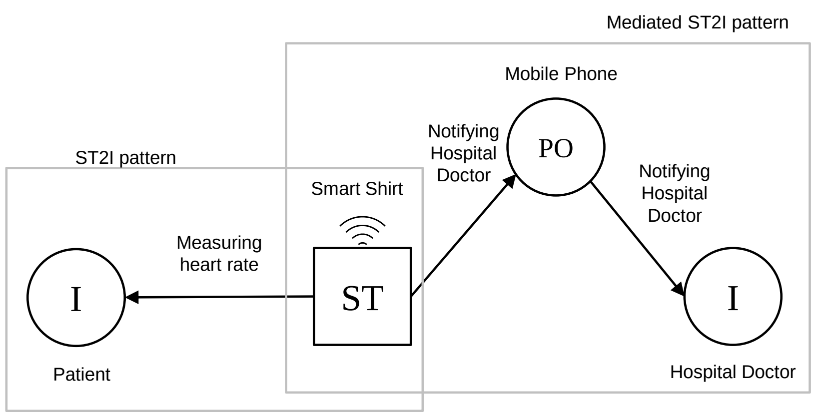


Figure 4. Smart Action of the Smart Shirt

As we can see, the smart action is derived from activity theory and extends this theory as to no longer limiting the roles of subjects to individuals and physical objects as tools or objects. However, the role of the subject is extended to physical objects that are enhanced with connectivity and acting capabilities, and thereby are transformed into smart things. Consequently, we define a smart action as an interaction in which smart things act as a subject or a tool and perform self-dependent actions. As our findings show, smartness does not come into existence, solely by equipping physical objects with information technology, but rather through the use of those objects in specific contexts and interactions that they take part in. A smart shirt, for example, could serve as a shirt that a person wears to feel warm. In this case, the shirt would not take part in any smart action pattern but would just be the object that the subject (i.e., individual) acts upon (i.e., wearing it) to achieve a desired outcome (i.e., feeling warm). Only through the use of the smart shirt in the context of a health-problem and interactions with the patient and the doctor does the smartness emerge. Hence, smartness depends on the context and emerges through self-dependent actions.

4.2.2 Input, Output, Environment, and System

Having provided a detailed depiction of interactions involving subjects and objects within a smart action, we now focus on the initiation, context, and outcome of such interactions (Figure 5).

Every interaction is initiated by an *input*. The input originates from the surrounding environment (Baird & Riggins, 2016; Olsen & Tomlin, 2020) and is either of *physical nature* (e.g., rain, sunshine) (Cu et al., 2017; Novales et al., 2016) or of *digital nature* (e.g., notifications, battery status) (Flath et al., 2012; Püschel et al., 2016). Subjects can initiate smart actions autarkically. In a smart factory, for example, machines can observe their own condition (e.g., temperature) and initiate preventive maintenance measures independently of external inputs (Berger et al., 2019; March & Scudder, 2019). Yet, a trigger reacting to a certain threshold or event leading to the smart action always exists.

The *output* of the interaction is also either of *physical* or *digital nature*, or *both* (Berger et al., 2018). After capturing the input, the subject perceives the input, processes the information, and carries out an action upon the object. This action produces an outcome, which influences the surrounding environment or triggers new interactions within the system of a smart action. To return to the example of smart charging, when electric power prices reach a certain level, a smart charging system (i.e., subject) is triggered via a digitally transmitted notification (i.e., interaction) to perform the action of charging upon an object (e.g., electric vehicle) (Brandt et al., 2017). The decline of the power price is the input that comes from the surrounding environment (e.g., the energy broker).

Environment describes other systems or actors that surround the system and which it interacts with or somehow affects (Miller, 1965). Overall, we could extract two types of environmental changes from the literature, namely changes to the *physical environment* (e.g., Chasin et al., 2020, Corbett & Mellouli, 2017, Novales et al., 2016) and changes to the *non-physical environment* (e.g., Baird & Riggins, 2016, Paukstadt & Becker, 2021, Kaldewei & Stummer, 2018). Corbett and Mellouli (2017), for example, describe a smart wastewater management system in a smart city that automatically diverts wastewater to retention basins in case of impending overflow based on underwater sensors. In this case the overflowing water triggering the diversion represents a physical change of the environment. As an example for a non-physical change to the environment, Paukstadt and Becker (2021) describe smart storage devices that automatically buy stored energy at low cost and sell stored energy when energy prices are low.

Coding the literature, we asserted that the actors and components of a smart action can always be considered part of a *system*. We draw from general systems theory when building relations between the identified concepts from literature. At the core of general systems theory is the understanding of a system as an organized whole and that interactions of the system with the surrounding environment take place for the purpose of exchanging energy or matter (Bertalanffy, 1972). The system's behavior is influenced through information exchange between the system's elements and the environment. A system is characterized by the reception of inputs (e.g., information, energy, or matter) from sub-systems or the environment, the transformation of inputs into outputs and the transfer of the outputs to other parts of the system or the environment (Miller, 1965). A system is a set of elements who/which interact with each other and with its surrounding environment (Runde & Faulkner, 2019) as subjects and objects do within the smart action. In IS literature, we found actors and components interacting in a *single system* (Bomhard & Wörner, 2016; Fernando et al., 2016). as well as systems interacting with other systems, forming a *system of systems* (e.g., Baird & Riggins, 2016, Bilstein & Stummer, 2020, Niemimaa, 2016). In Bomhard and Wörner (2016), the smart heating IS and the residence owner interacting with each other build a single system. Baird and Riggins (2016), on the other hand, describe systems of smart things that interact with each other as well as with other systems of smart things, forming systems of systems is created.

As we provided a detailed overview of the actors and components of a smart action, as well as the interactions between them, we now illustrate the relations between the aggregate dimensions expressed by the arrows between input, output, environment, subject, and object in Figure 5. Input, output, and environment are constructs that form the external base of subject-object interactions. The subjects and objects of a smart action form a system by interacting with each other and, thereby, become actors and components of the system. The input triggers the interaction within the system. The output finally exits the system into the environment and influences constructs or systems in the surrounding environment (Baird & Riggins, 2016) or forms the input for a new interaction within the system. In the case of physical input, sensors or human receptors, such as eyes or ears, receive the input. Digital input is received in the same way (i.e., by digital receptors) through digital components that can perceive in the digital world (Song et al., 2019). For example, digital receptors extract energy prices via the internet and take them as a digital input in a smart grid system.

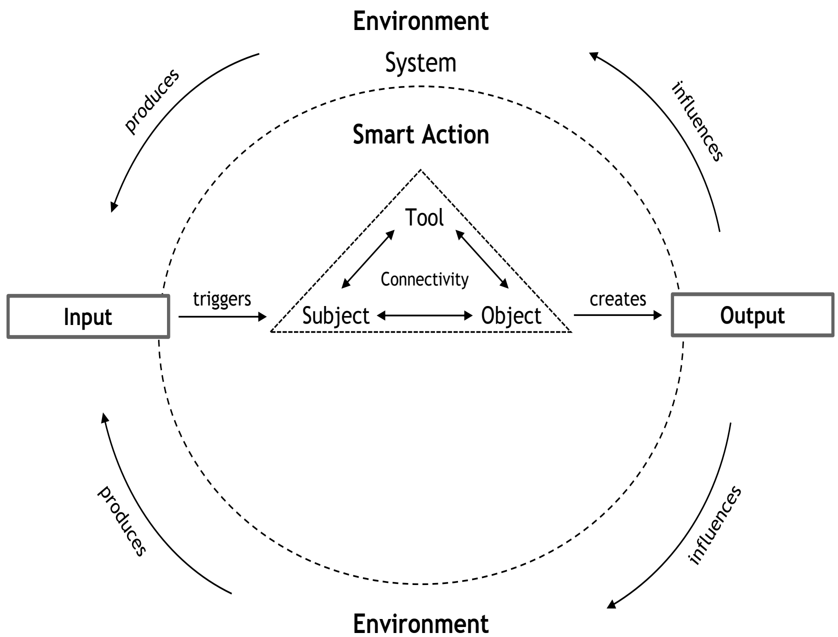


Figure 5. Input, Output, Environment, and System

4.2.3 Steps of Information Processing conducted by the Subject

Information processing includes capturing, transmitting, storing, retrieving, manipulating, and displaying information (Alter, 2019; Porter & Heppelmann, 2015; Püschel et al., 2020). It is the precondition for smartness and requires a facilitative technology stack (Porter & Heppelmann, 2014; Yoo, 2010).

In our analysis, we identified a pattern (i.e., sequence) of information processing steps the subject usually carries out – *perception, interpretation*, *decision*, *behavioral response*, and *learning* – for processing input into information (Fischer et al., 2020; Song et al., 2019). We drew from information processing theory when deriving the information processing steps (Greifeneder et al., 2017). Information processing theory cognition offers a framework for human information processing. However, we discovered that this framework can be applied to smart things as well. Figure 6 illustrates the information processing as it is performed by the subject and thereby happens within the smart action. To be more specific, within the process, the input is transformed to afford smartness, resulting in an output that is perceived as smart. In the following, we describe the steps of information processing and go into more detail about what this means in the context of a smart action.

Perception refers to perceiving information from surrounding actors, components, or other influences. When looking at a subject's actions, we found that physical sensors, digital sensors, and human receptors play an important role. Physical sensors can observe their environment, for example, measuring temperature or velocity (Bomhard & Wörner, 2016). Digital receptors collect digital traces and perceive information, such as incoming e-mails or digital trails from social software applications (Newell & Marabelli, 2014; Song et al., 2019). Human receptors are human organs (e.g., eyes or ears), which can observe the environment.

Interpretation involves structuring the incoming data and extracting meaning (i.e., information) from it, whereas *judgement/ decision* involves determining a consequence and deciding on how to react to the information, which may be processed by either a human brain or algorithms. These constructs execute a process, which consists of two steps. The first step is the interpretation of a perceived input, which means that the subject extracts meaning from the incoming data (e.g., Slavova & Constantinides, 2017; Son et al., 2020). The second step involves the derivation of a consequence, and decision-making based on the extracted meaning (e.g., Brauer et al., 2015; Weber, 2017). Either a human brain (Warkentin et al., 2017) or an algorithm embedded in or connected to a smart thing (Köpp et al., 2013) executes both steps. The brain uses its *organized knowledge* stored in its memory as experience or logic. An algorithm, in contrast, processes the information based on computing functions and available data (Fischer et al., 2020). Such algorithms could exemplarily decide to take option A, B, or C. At this point, an action becomes smart in that the interpretation is not trivial. Indeed, the understanding of whether an interpretation is trivial is dynamic and depends on the observer. Emerging from an age of trivial logic, contemporary smart actions could soon be perceived as trivial as computing power and the expectations of observers increase.

Finally, the last step of the smart action is the *behavioral response* (i.e., carrying out the decision), which manifests in a physical or digital reaction. A physical reaction can be a mechanical movement of a physical object (Fleisch & Thiesse, 2007). A digital reaction is a reaction that occurs exclusively in the digital world, such as sending an e-mail (Püschel et al., 2016) or providing digitally perceptible information (Alsaqer & Hilton, 2015). The executed behavioral response of the smart action then leads to an output or a second smart action. The object of the first smart action can then execute the second smart action, at which point it becomes the subject of the second action. For example, a smart shirt continuously perceives the wearers' heart rate (perception) and interprets a critical status (interpretation). Based on the analysis of the data, the smart shirt decides whether to take no action, send a notification, or automatically call the ambulance (judgement/ decision). While interpreting and deciding, the smart shirt draws on its data/experience (organized knowledge). Finally, the shirt carries out the decision (behavioral response) (Ma et al., 2017).

Learning refers to the evaluation of the output (e.g., Bichler et al., 2010; Baptista et al., 2020). After the subject has acted on an object in the form of a behavioral response, it analyzes the output and evaluates the result of the action. Smartness involves the subject learning from the result, with subsequent actions influenced and optimized by the learning. In IS literature, we identified different types of learning. On the one hand, we found simple types of learning, which we describe as *basic learning*. Kaldewei and Stummer (2018), for example, describe smart home systems learning the resident's temperature predilections over time and adjusting the temperature control accordingly. On the other hand, in IS literature, many studies associated smartness with more complex types of learning (e.g., Brandt et al., 2017, Paukstadt & Becker, 2021, Trunk et al., 2020), which we call *advanced learning*. Paukstadt and Becker (2021), for example, describe self-learning smart energy systems that use AI to optimize energy consumption without any action from the user.

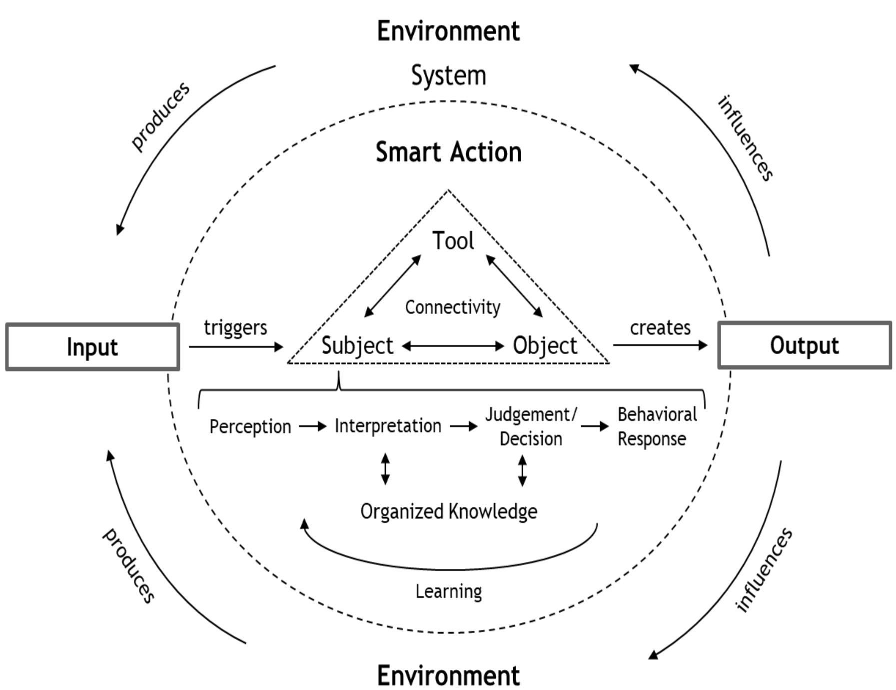


Figure 6. Information Processing within the Smart Action

Regarding the procedure of information processing, we observe that smartness operates on a continuum and offers different levels of smartness. For example, a basic level of smartness would be a smart home system that provides dinner proposals for the resident based on last week's dinner choices (Valogianni et al., 2014). Such recommendation relies on learning based on small and simple amounts of data. A more advanced level of smartness would be, for example, a smart grid that anticipates the energy consumption based on historical energy consumption data and provides sophisticated decision support for the adaption of energy consumption (Warkentin et al., 2017). The most advanced form of smartness is autonomous behavior, which means that, for example, a smart farm autonomously adapts the farm conditions (e.g., irrigation) based on environmental data (Cu et al., 2017). Within the different levels of smartness, the information processing steps occur in different ways. The behavioral response in basic smartness is a simple proposal for an individual. In autonomous smartness, however, the behavioral response is an independent adaption of conditions. Interpretation in basic smartness can mean providing individualized proposals based on simple if/else statements. In advanced smartness, the interpretation of the perceived information means analyzing large and complex datasets considering many features and parameters and decoding this data for humans to be able to handle the information. Hence, smartness moves on a continuum and the level of smartness depends on the context, the complexity of the data analysis as well as the use of the smart thing. For example, in smart homes, the level of smartness also depends on the interactions of the resident and the smart home system. Through interacting with the smart home system over a period of time, the smart home system receives feedback and learns and adapts based on the user's feedback. While only being able to provide simple proposals based on a small number of perceived preferences at the beginning of the use, the smart home system can develop to providing more advanced proposals. These advanced proposals are based on many weeks or months of learning and the smart home system is finally able to autonomously adapt conditions, such as room light, temperature, or buying cooking ingredients.

4.2.4 Definition of Smartness

Having described in detail the smart action and its surrounding concepts, we introduce a definition of smartness to provide a common understanding of smartness in IS research. Recent publications even in high-quality IS journals (e.g., Senior Scholars' Basket of Journals) did not use 'smartness' consistently or in a well-grounded manner, underlined by the divergent definitions we present in Appendix A. Our definition of smartness respects existing definitions in an IS context, takes into account the insights on smart action, and establishes a general definition of smartness that covers all application domains. We define smartness as the *participation of things in one or more smart action patterns where they show the ability to interact, react, anticipate, and make self-dependent decisions*. This general definition has different manifestations in different IS problems and contexts. In the smart home context, for example, smartness is related to interactions with individuals and learning individuals' preferences over time and adapting to those preferences (smartness in the sense of interaction with individuals) (Fernando et al., 2016). Smartness in smart grids, however, refers to analyzing large amounts of data in real time and making economic and profitable decisions (smartness in the sense of economic decisions) (Warkentin et al., 2017). In the smart city context, smartness means collecting data about the city (e.g., the abundance of trash cans, water pollution, etc.) and taking measures that serve the common good based on this data (e.g., reducing traffic volume, lowering environmental pollution) (smartness in the sense of improvement of the common good) (Corbett & Mellouli, 2017). Smart factories, on the other hand, collect machine data and anticipate potential machine failures based on this data (smartness in the sense of failure prevention) (Häckel et al., 2017). Hence, the components of our general definition manifest differently in different contexts.

5 Theoretical Embedding

Applying GT techniques during the analysis of the literature includes the constant comparison of achieved insights with existent research and the theoretical sensitivity for related concepts and theories (Urquhart, 2013; Wolfswinkel et al., 2013). As we already outlined in the method and results section, we compared and enriched our identified concepts with existing theoretical concepts. We thereby moved from describing the observed phenomenon to generalizing several aspects of that phenomenon and were able to identify the boundaries of this generalization. Constant comparison is the discussion of concepts that emerge from the data sample with similar concepts that emerge in other situations (Glaser et al., 1968). This theoretical embedding strengthens and justifies concepts and allows to produce grounded generalizations on a phenomenon, to finally produce more formal theory (Urquhart, 2013). So, in our literature review, we constantly looked for potential theories that fit the identified concepts and themes. This resulted in three adjacent theories that have already been applied in IS research (Barann, 2018; Kalgotra et al., 2017) and in which we could embed our findings. The theories we found are activity theory, general systems theory, and information processing theory. We also considered other theories for theoretical embedding such as, for example actor network theory. However, the three theories proved to explain the most of and fit best to our theoretical concepts. For example, activity theory focused on goal-directed actions that also supported our focus of interaction between smart things and their environment. Actor network theory, for example, tended to focus too strongly on negotiation and trying to maneuver actors into a network (Akrich, 1992). Table 3 provides an overview of how the concepts that we found in IS literature fit with the concepts of these adjacent theories.

Table 3. Mapping of Concepts used in the Adjacent Theories with the Concepts found in our Literature Review

Theory	**Concept**	**Description of the Concept in the Theory**	**Our Usage/ Application of the Concepts**
Activity Theory	Subject	It carries out actions upon the object	Smart thing or human being carrying out an action upon an object
Activity Theory	Object	The subject acts upon it	Smart thing, human being, or physical object being acted upon
Activity Theory	Tool	The subject uses it as an intermediary artifact	Intermediary artifact being used by the subject to carry out the action
General Systems Theory	Input	It enters a system and triggers interactions between the elements of the system	Physical or digital input triggering an action by the subject
General Systems Theory	Output	It is created through subject-object-interactions	Physical or digital output is the result of the action
Information Processing Theory	Perception	The result when the subject perceives internal/external stimuli	Subject using sensors, human receptors, or digital receptors to perceive the input
Information Processing Theory	Interpretation/Decision Making	The cognitive process of interpreting external stimuli and, subsequently, making a decision about how to act	Cognitive processes of the subject using either the brain or algorithms to interpret the perceived input and make a subsequent decision
Information Processing Theory	Organizational Knowledge	Memories or stored data used to influence interpretations and decision making	Subject basing its interpretation and decision-making on either its memory or its data storage
Information Processing Theory	Behavioral Response	The behavior of the subject after having processed the information	Subject acting upon the object, based on the processing of the input

5.1 Activity Theory

After structuring the aggregate dimensions found in the IS literature, we discovered that the aggregate dimensions *subject*, *object*, and what we call *tools* exhibit strong similarities to activity theory. Activity theory formalizes the interaction of a subject with an object through the use of tools. In the theory, the subject is an acting human being that performs an action directed to an object (Benbunan-Fich, 2019). The tool serves as an intermediator for the action of a goal-directed subject (Allen et al., 2013; Karanasios & Allen, 2014). Describing how an activity is structured, activity theory provides an intricate perspective on interactions among subjects and objects (Engeström, 1987, 1999). To produce a desired outcome, the so-defined activity consists of various actions the subject carries out on the object (Igira, 2008). As activity theory generally assigns the role of the subject to human beings, we apply activity theory in an extended manner by not only considering human beings as acting subjects, but also smart things. In both activity theory and our concept, interaction takes place either directly or indirectly via the use of an intermediating tool. Activity theory suggests that smartness is not solely an individual trait, but rather a product of social interaction and the tools and resources available to an individual. In the context of smart things, this means that smartness is not just about having specific properties such as data analytics algorithms, but rather about using them in meaningful and purposeful activities with others. Additionally, activity theory emphasizes the importance of context for actors to achieve a desired outcome. This means that the ways in which technology is used, the goals and purposes of its use, and the cultural and social context in which it is used determine how smart the technology is. On this basis, we use activity theory as a meta-theoretical lens to embed our findings within justificatory knowledge.

5.2 General Systems Theory

We also found that the aggregate dimensions *input*, *output*, *environment*, and *system* fit general systems theory (Bertalanffy, 1968). According to general systems theory, a system contains interactions between its elements, receives inputs from sub-systems or the environment, and transforms these inputs into outputs (Miller, 1965). General systems theory is a widely used theory in IS research, and has often been used as a theoretical lens, for example, to theorize IT artifacts (Matook & Brown, 2017). In our analysis of IS literature, we also identified different elements interacting with each other and the environment, thereby building up a system. In line with general systems theory, we discovered interactions between subjects, objects and tools that are triggered by inputs from the environment or parts of the system and producing outputs. Köpp et al. (2013), for example, describe a smart meter system that autonomously turns on the washing machine in case of solar energy availability. The smart meter system thereby becomes an active processor, transforming an input from the environment (i.e., solar energy availability) into an output (i.e., turning on the washing machine). Overall, general systems theory provides a framework for understanding the behavior of complex systems and the ways in which their parts interact to produce emergent properties and behaviors. It can be useful for understanding the nature of smartness and how it arises in various systems. General systems theory suggests that a system is more than the sum of its parts and that the interactions between the parts contribute to the overall functioning and efficiency of the system. In terms of smartness, general systems theory helps understanding that smartness emerges from the complex interactions between the parts of a system, and that it is not solely a property of any single part. Due to the similarities of general systems theory and the concept of a smart action, we use general systems theory as a theoretical lens for the aggregate dimensions input, output, environment, and system.

5.3 Information Processing

We found that perception, interpretation, judgement/decision, and behavioral response are central to smart actions and fit information processing theory. This theory describes the processing of information in any manner detectable by an observer (Greifeneder et al., 2017). After perceiving an input, and decoding and interpreting it, the person draws a conclusion using the interpretation and decides how to respond. Finally, a behavioral response is carried out (Greifeneder et al., 2017). Information processing theory suggests that smartness is related to the ability to process and manipulate information effectively. Smartness thus includes the ability to recognize patterns, make decisions, and solve problems. Combining the results from our literature review with insights from information processing theory, we can infer that smart things are designed to mimic the human information processing system. They can absorb information through various sensors and input devices, process the information using algorithms, and then output the results through various means such as display screens or output devices. We can also learn that smart things are designed to be efficient in their processing of information. They can quickly and accurately process large amounts of data, often at a much faster rate than humans can. Through this processing capability, they can perform tasks that would be too time-consuming or complex for humans to do.

6 Discussion

Research on smart things and services is attracting ever more attention. Yet, while the term *smart* is widely used in IS research, a clear understanding of smartness is lacking. We, therefore, investigated smartness in the IS literature and conceptualized how it becomes manifest. By using GT techniques based on a literature review (Wolfswinkel et al., 2013), we developed a concept describing the dynamics of smartness in IS, which expresses itself in the form of smart actions. The concept of smart actions involves constructs that take part in the action and their interrelations. Further, it emphasizes that smartness only comes into existence and becomes perceivable through smart actions.

6.1 Theoretical Contribution

Previous IS research explored a wide range of IoT-based application domains, evident in the vast number of publications and calls for papers by various IS communities and journals (e.g., Warkentin et al., 2017). However, to the best of our knowledge, and as seen in the literature search, neither a conceptualization of smartness nor a common understanding exists of how smartness expresses itself. We define smart actions and reveal that smartness becomes manifest in a smart action. Our research also sheds light on the actors and components involved in a smart action and how they interact. Lastly, we identify how smart actions are initiated and which outcomes they generate. Our research contributes with a Type I theory for analysis and description (Gregor, 2006). Theories for analysis and description describe specific characteristics of individuals, groups, or events and describe "what is". They are used when little is known about a particular phenomenon. As few research exists on the conceptual nature of smartness in IS literature, our theory for analysis and description lays the foundation for a structured discussion of smartness in IS. The conceptualization of smartness lays the ground for further theorizing, for example, as for providing a better understanding of how smart things relate and affect other actors and for deriving specific design recommendations for smart things.

The first theory-specific contribution of our study is to reveal that smartness becomes manifest in smart actions. We specify smartness and argue that smartness strongly relates to actions. By investigating research on smart things in different domains of application (e.g., Püschel et al., 2020), we found that these applications become smart through actions and interactions among actors. We found that smartness only becomes perceivable with the exchange of information and in the corresponding actions that take place. Alter (2019) provides a foundation for our research as he analyzes important characteristics of smartness in the context of devices, and differentiates between the use of predefined data and context-related knowledge for information processing. We build upon these characteristics and develop the dynamic concept of a smart action. While Alter (2019) states that an entity becomes smart through automated capabilities and information processing, we further investigate the actors and components with which the entities interact, as well as the context in which information is processed (e.g., how information processing is initiated). We develop six smart action patterns that provide a detailed description and understanding of the interplay between the actors involved in smart actions. Furthermore, we examine the interplay between interpretation, decision-making, and organized knowledge in more detail as we identify, for example, that smart things use algorithms and data storage during interpretation and decision-making. We thus focus on the emergence of smartness.

Secondly, we define the concept of a smart action. We bring clarity to the notion of a smart action as we provide a definition based on the extracted concepts from the literature on smartness in IS research. Thereby, smart things are at the core of smart actions and display as a vital building block for creating smartness. The provided definition is not limited to a specific domain of application. Further, the definition emphasizes that smart things are capable of performing self-dependent actions. We ground our understanding on Alter's (2019) definition of smartness and assert that actual smartness is created through interactions of smart things with other actors or even with themselves. A smart shirt, for example, interacts with its wearer by measuring the heart rate and then interacts with a physician by sending a notification about a critical heart rate (Ma et al., 2017). The example shows that smartness only comes into existence in the course of a smart action when smart things are interacting with other entities in their surrounding environment. Our definition implies that smart things must have the ability to decide for themselves or, in a more technical manner, have a certain degree of freedom in decision-making. They can take over and enhance the output of tasks previously carried out by humans (Alter, 2019; Beverungen et al., 2019; Fernando et al., 2016; Oberländer et al., 2018; Weber, 2017). These characteristics allow smart things to participate as acting subjects in smart actions while, however, not every action carried out by a smart thing must, per se, be considered smart.

The third theoretical contribution of our paper is to reveal the underlying actors and components involved in smart actions, and how these interact. These actors and components repeatedly feature in the literature we reviewed. We use existing and well-established theories from other domains to embed our findings and enable us to understand and analyze smart actions more comprehensively. Hence, our conceptualization of subject-object interactions allows for a better understanding of the real-world context and the relationship between the two actors, as clear characteristics are defined for subjects and objects, facilitating a more structured analysis of role allocation. In this context, we discovered that certain actors and components of smart actions are subjects and others are objects. In relation to selected constructs, smart things or individuals can take on the role of the subject. Smart things, individuals, and physical objects can be the object in a smart action: that which is acted upon to realize the smart action. Similar to our research, Runde and Faulkner (2019) conceptualize digital objects, describe their properties, their roles in a system, and how they interact with their environment. Nevertheless, their research differs fundamentally from ours as they define any object containing at least a single bit string as a digital object. By this definition, even simple programs or files on a computer are digital objects. Our research, in contrast, refers only to smart things with acting capabilities and autonomy.

Fourth, we conceptualize how smart actions are initiated and which outcome they generate. Our study offers a theoretical lens to analyze smart actions in a structured manner and to develop new theories, such as theories for explanation and prediction as well as for design and action (Gregor, 2006). We found that an input of a physical or digital nature triggers the action. Berger et al. (2018), for instance, provide knowledge on the nature of DTs and claim that the input and output are physical or digital. We build on this conceptualization, revealing how input and output are connected and which interactions take place in between. Beverungen et al. (2019), for example, initially came up with the idea of conceptualizing smart things as boundary objects in interactions between service providers and service customers. Yet, they did not analyze the inner nature of smart things. Püschel et al. (2020) did indeed analyze the inner nature of smart things but focused on a fixed set of characteristics for their taxonomy as opposed to the dynamic concept we provide in our study. Our action-oriented concept provides an understanding of how interactions are triggered, what happens afterward, how smartness is created during the action, and which outputs the system generates. Finally, we discovered that smart things show human-like information-processing capabilities based on algorithms and data storage. Smartness in technological applications can, thus, enable applications that act autonomously. As such, our study integrates cognitive information processing into the interactions taking place within smart applications.

6.2 Limitations, Future Research, and Conclusion

In this paper, we used GT techniques based on a structured literature review to conceptualize smartness within IS research. Our findings lead to the concept of a smart action, in which physical or digital inputs trigger interactions between actors and components in a system and produce a physical or digital outcome. We also discovered that individuals as well as smart things can conduct cognitive information-processing steps. Having identified the underlying information-processing steps, we developed a concept illustrating how inputs and outputs, actors and components, and the surrounding environment are related to one another (see Figure 6). The developed concept allows for analysis of smart actions, describes how they unfold, and can be used as a theoretical lens in future IS research, while it can be also developed further for use in domains other than IS.

As with any research project, our work is subject to limitations. Our interpretation and use of the concept of a smart action is restricted by the research field, search terms, and literature sample of our study. First, although other research fields also investigate smart phenomena, we only examined studies from the IS domain. Not including research from adjacent topics, such as public sector research, might have impacted the results, as such research brought a significant number of smartness-related publications. To further generalize the concept of a smart action, domains such as biology and psychology could provide valuable insights and help to better understand und further specify the concept (Veenhoven & Choi, 2012). Interesting approaches for future research could be the identification and embedding of further concepts from other domains in order to better understand and structure certain contexts. For example, the concept of cognitive skills (e.g., perceiving, recognizing, predicting) (Rai et al., 2019; Russell & Norvig, 2016), possessed by human beings or AI, could enrich the concept by better understanding the process of learning and how it influences the smart action. Further, our research approach is limited by the terms we used in our database search. To provide a wider understanding of the meaning of the term “smart” and “smartness”, one could also investigate related terms and antonyms. It should also be noted that we did not search within all available databases but limited our research to a selected sample of IS journals and conferences. The sample included a considerable number of scenarios that relate to IoT, indicating that it has a significant influence on IS research. Yet, due to the above-mentioned limitations concerning fields of research and search strategy, the DTs (i.e., smart things) that form the focus of our study do not provide a complete overview of the category. Thus, future research should consider applying other types of theory to investigate and better understand smartness. Our result is a theory for analysis and description (Gregor, 2006), and provides a solid foundation for researchers applying more advanced, complex, and detailed theories. We particularly recommend building on our findings with theories for explanation, which promise a deeper understanding and explain how and why the phenomenon occurs. Future research could disclose different procedures of how smartness occurs in IS, how interactions take place, and how they are perceived. Such studies could further answer the questions if different types of observers of a smart thing perceive a smart action in different ways, and whether input and output collude in similar ways. Investigating case studies of smart actions to better understand the process in real-world applications or case studies of smart actions, which lead to unwanted deviations from an expected outcome, would improve understanding of underlying concepts and systems. Following this, we also recommend theories for design and action to guide researchers and practitioners in how to build and design systems capable of carrying out smart actions. Designing guidelines displays a promising step to providing a strong contribution, especially for practitioners. Even further, the development of design methodologies and processes for smart things and systems represents an important and promising field of research. Lastly, our conceptualization of smartness may be limited in its generalizability since we focused on the context of interactions between different actors involved in smartness. However, in other contexts, such as smart service systems, smartness may be conceptualized in a different way and may not result in the concept of a smart action.

In terms of our contribution, we discovered during the analysis of our literature sample, that different forms of smartness exist. These could be classified hierarchically from very basic to very advanced. Knowledge of the different levels of smartness and their interdependencies could be enhanced via the development of, for example, a maturity model. As our conceptualization of smartness focuses on technology and devices, future researchers could further examine the conceptualization from the service perspective. This could include investigating whether the conceptualization is applicable to domains or needs to be adapted and extended.

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Appendix A

Appendix A provides an overview on the different schools and understandings of smart or smartness as present in IS literature. The different understandings provide the basis for a general and consolidated definition of smartness.

Table A1. Different Understandings of Smart and Smartness in IS Literature

Authors (year)	**Definition**	**Emphasis and focus of definition**	**Referring/ borrowed characteristics**
Alter (2019)	"Purposefully designed entity X is smart to the extent to which it performs and controls functions that attempt to produce useful results through activities that apply automated capabilities and other physical, informational, technical, and intellectual resources for processing information, interpreting information, and/or learning from information that may or may not be specified by its designers" (p. 384).	Smart things using information to perform autonomous actions; Focus on technology	"the ability to interact, react, and take their own decisions"; "autonomous actions" The characteristic describes advanced capabilities of smart things (processing information, taking autonomous decisions)
Beverungen et al. (2017)	"Smart products use sensors to obtain contextual data, exchange data with other actors, store and process data locally, make autonomous decisions, and act physically by means of actuators" (p.8).	Smart things interacting with other actors and making autonomous decisions; Focus on technology	"the ability to interact, react, and take their own decisions"; "autonomous actions" The characteristic describes smart things taking on human characteristics and acting independently
Brandt et al. (2017)	"Smart grids are described as 'a convergence of information technology and communication technology with power system engineering' (Farhangi, 2010, p. 19), exemplifying cyber-physical characteristics" (p.208).	Smart things having communication and interaction capabilities; Focus on technology and service	"the ability of smart things" The characteristic describes the blurring line between technology and service. Things have an ability. They thus can be an actor.
Corbett et al. (2017)	"Smart cities seek to leverage advanced communication technologies and IS in order to improve all areas of the city administration, enhance citizens' quality of life, engage citizens and provide more sustainable and resilient public services" (p. 428).	ICT to improve various areas of a city; Focus on service	"enhance the output of such tasks" The characteristic describes the use of DTs to generate better results than could human beings.
Fernando et al. (2016)	"The term 'smart home' […] has been defined as "a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond" (Harper, 2003, p. 17)." (p.4).	Autonomously-acting smart things to improve a resident's life; Focus on technology and service	"the ability to interact, react, and take their own decisions" The characteristic describes advanced abilities of smart things (anticipating, interacting with humans).
Oberländer et al. (2018)	"Smart things, as physical objects with embedded technology, consist of various human-shaped physical and digital components" (p.491).	Transfer of human characteristics to smart things; Focus on technology	"the ability of smart things" The characteristic describes the increasing integration of human-like abilities into DTs.

Warkentin et al. (2017)	"The smart grid superposes a communication network over the existing electrical grid, which enables managers to collect information about electrical power production, transmission, and consumption in order to monitor its operational state and, thereby, improve its efficiency and stability" (p. 760).	Communication and network properties as well as the ability to collect and analyze data; <u>Focus on service</u>	“the ability of smart things” The characteristic describes the increasing fusion of the physical and the digital world and the effects on services.
Weber (2017)	“A connected ‘smart world’ with sensing and control features embedded in products is likely to lead to a significant qualitative change of lifestyle of the humans ‘in the loop’” (p.343f.).	Embedding of sensing and control features in products; <u>Focus on technology</u>	“the ability of smart things”; “enhance the output of such tasks” The characteristic describes the benefits that the use of DTs could bring to increase humans’ quality of life.

Appendix B

Appendix B provides a reference list of all papers included in the literature review.

Table B1. Overview of the Papers included in the Literature Review

References used in the literature review
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Appendix C

Appendix C provides an overview of the data structure and shows a graphical representation of the coding process from 1st order concepts to 2nd order themes to aggregate dimensions. In the left column under the heading “1st Order Concepts”, a sample of 1st order concepts from the literature review is provided.

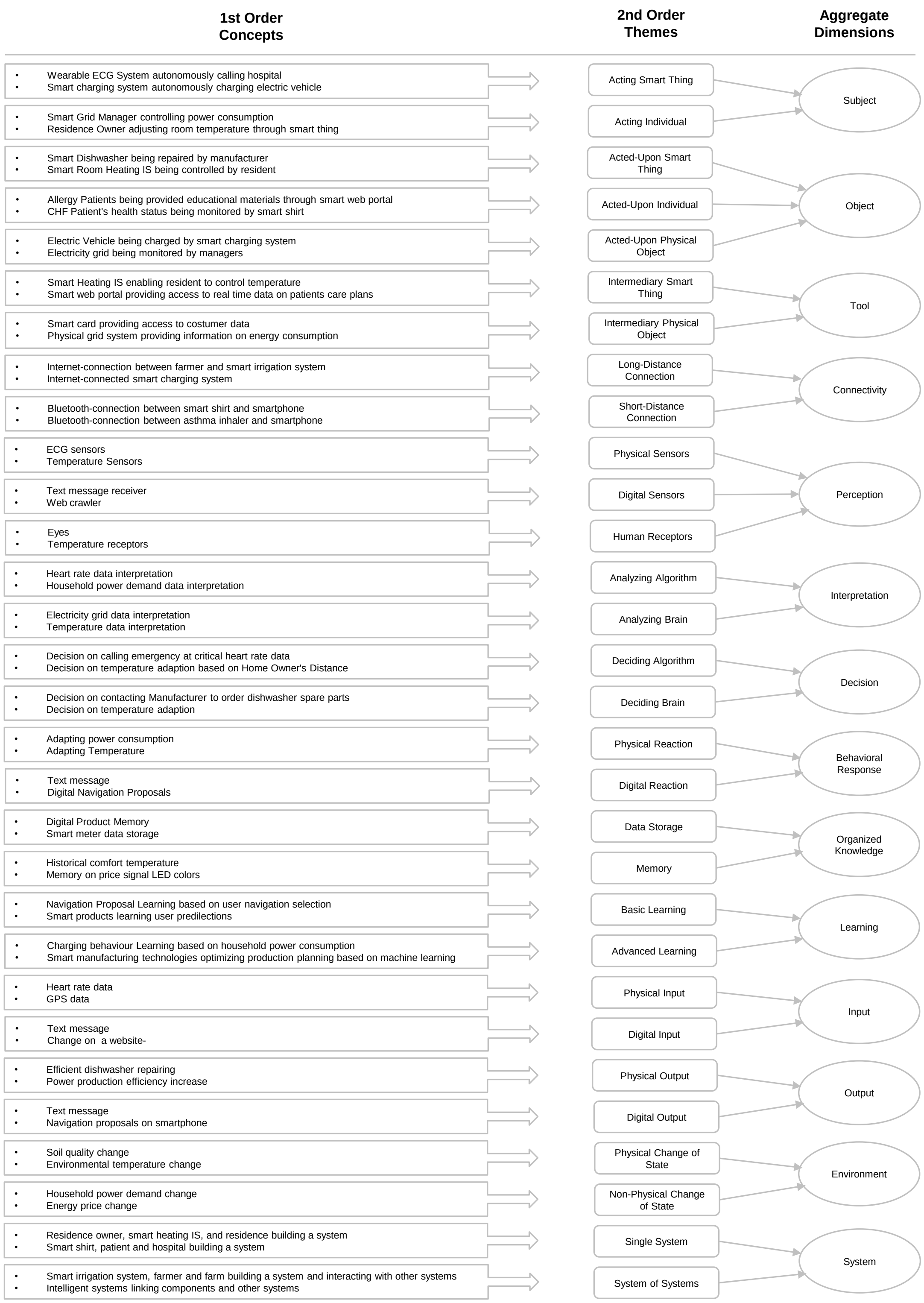

Figure C1. Data Structure

Appendix D

Appendix D provides a detailed overview of the data structure and of how first-order concepts link to second-order themes and aggregate dimensions. It also provides justificatory references, showing which first-order concepts we extracted from which papers of the literature review.

Table D1. Data structure and the Relations of the Findings to the Papers Analyzed

Justificatory References	1st Order Concepts	2nd Order Themes	Aggregate Dimensions
Busquets et al. (2010), Barlow and Dennis (2017), Vervest et al. (2004), van Hillegersberg et al. (2004)	Employee acting within a smart business network	Acting Individual	Subject
van Putten et al. (2011)	Dishwasher Customer ordering substitute component		
van Putten et al. (2011)	Dishwasher Manufacturer delivering substitute component		
Warkentin et al. (2017), Kranz et al. (2010), Ketter et al. (2016)	Smart Grid Manager controlling power consumption		
Bomhard and Wörner (2016)	Residence Owner adjusting room temperature based on smart heating IS recommendations		
Cu et al. (2017)	Farmer monitoring irrigation based on recommendations from smart irrigation system		
Slavova et al. (2017), Kranz et al. (2010)	Energy consumer adjusting energy consumption behaviour		
Naik and Fritzsche (2017)	Human cognitive capabilities producing effective solutions		
Benbunan-Fich (2019)	human being interacting as a subject		
Ma et al. (2017)	Smart Shirt autonomously calling hospital	Acting Smart Thing	
van Putten et al. (2011)	Smart Dishwasher providing information on broken component		
Warkentin et al. (2017), Ojo et al. (2014), Köpp et al. (2013), Kranz et al. (2010)	Smart grid providing information on power consumption		
Novales et al. (2016)	Sensor-equipped autonomous vacuum cleaner		
Bomhard and Wörner (2016)	Smart Room Heating IS autonomously adjusting room temperature		
Püschel et al. (2016)	Smart thing interacting with consumers and other smart things		
Vervest et al. (2004)	Conscious Machines acting in a smart business network		
Alsaqer and Hilton (2015)	Indirect Wayfinding System proposing navigation routes		

Cu et al. (2017)	Smart Irrigation System providing recommendations on irrigation		
Brandt et al. (2017)	Smart charging system autonomously charging electric vehicle		
Slavova et al. (2017), Flath et al. (2012), Kranz et al. (2010)	Smart meter collecting and providing usage data to consumers		
Fleisch et al. (2007)	Smart toaster printing weather report on toast		
Corbett et al. (2017)	Wastewater management system autonomously detouring waste water		
Fernando et al. (2016), Kuebel et al. (2015)	Smart home performing automatic resident adaptions		
Wastell et al. (2006), Valogianni et al. (2014), Barth et al. (2017)	Smart city information technology monitoring operations across the city		
Oberländer et al. (2018), Barann (2018)	Smart thing as an autonomous actor		
Ziekow and Strueker (2011), Baird and Riggins (2016)	Smart Device performing actions affecting its environment		
Häckel et al. (2019)	Smart objects controlling and monitoring the production process collaboratively through machine-to-machine communication		
Becker & Paukstadt (2021)	Smart GridBox optimizing energy flows in the home		
Lundin et al. (2017)	Smart trash bin measuring and visualizing filling level		
Niemimaa (2016)	Smart road signs changing road signs and closed signs remotely		
Naik and Fritzsche (2017)	Smart Toolkit proposing design solutions		
Kaldewei and Stummer (2018)	smart products reacting proactively to environmental changes		
Weber et al. (2017)	control features embedded in smart products		
Wickramasinghe and Haddad (2017)	Allergy Patients being provided educational materials	Acted-Upon Individual	Object
Ma et al. (2017)	CHF Patient's health status being monitored by smart shirt		
Alsaqer and Hilton (2015)	Elderly person being navigated by indirect wayfinding system		
Brandt et al. (2017), Flath et al. (2012)	Electric Vehicle owner profiting from automatic vehicle charging		
Slavova et al. (2017), Kranz et al. (2010)	Energy consumer profiting from automatic power loading		
Fernando et al. (2016), Wastell et al.	Smart home resident being acted upon		

(2006), Valogianni et al. (2014)	by smart home		
Falan et al. (2011)	Smart health applications collecting sensor-based health data to track the health status of an individual		
Becker & Paukstadt (2021)	Energy consumer profiting from optimized energy management		
van Putten et al. (2011)	Smart Dishwasher being repaired by manufacturer	Acted-Upon Smart Thing	
Bomhard and Wörner (2016)	Smart Room Heating IS being controlled by resident		
Niemöller et al. (2019)	Factory worker controlling smart thing via voice control		
Bomhard and Wörner (2016)	Residence being monitored by residence owner	Acted-upon Physical Object	
Cu et al. (2017)	Agricultural soil being irrigated by smart irrigation system		
Brandt et al. (2017), Flath et al. (2012)	Electric Vehicle being charged by smart charging system		
Slavova et al. (2017), Kranz et al. (2010)	Electricity grid being monitored by managers		
Fleisch et al. (2007)	Bread being pasted weather report by smart toaster		
Corbett et al. (2017)	Wastewater plant being monitored by wastewater management system		
Häckel et al. (2019)	Production plant being monitored by smart objects		
Falan et al. (2011)	Smart Consumer Empowered Diabetes Education System interconnecting service providers and health care consumers	Intermediary Smart Thing	Tool
van Hillegersberg et al. (2004)	Webservice enabling smart business networks		
Bomhard and Wörner (2016)	Smart Heating IS enabling resident to control temperature		
Wickramasinghe and Haddad (2017)	Smart web portal providing access to real time data on patients care plans		
Becker & Paukstadt (2021)	Web portal displaying energy flows		
Klötzer and Pflaum (2017)	Smart product enabling smart services		
Marinovici (2016), Petercsak et al. (2016)	Smart technologies as a tool in a smart city		
Oesterreich and Teuteberg (2017)	Smart glasses displaying 3D visual overlays for construction workers		
Niemöller et al. (2019)	Smart glasses enhancing technicians' capabilities		

March and Scudder (2017)	Smartphones mediating interactions between factory worker and smart factory machines		
Niemöller et al. (2019)	Smart glasses enhancing technicians' capabilities		
Li et al. (2009), McGrath (2017)	Smart card providing access to costumer data	Intermediary Physical Object	
Howell et al. (2016)	Smart card allowing administrators to monitor the location pattern of users		
Warkentin et al. (2017)	Physical grid system providing information on energy consumption		
Warkentin et al. (2017), Becker & Paukstadt (2021), Kranz et al. (2010)	Interconnected Smart Grid System	Long-Distance	Connectivity
van Putten et al. (2017)	Interconnected Dishwasher via internet		
Bomhard and Wörner (2016)	Interconnected heating IS via internet		
Cu et al. (2017)	Internet-connection between farmer and smart irrigation system		
Brandt et al. (2017)	Internet-connected smart charging system		
Slavova et al. (2017), Flath et al. (2012), Kranz and Picot (2012)	Smart meter connected via internet		
Fleisch et al. (2007), Kranz et al. (2010)	Smart toaster connected via internet		
Gascó (2016), Petercsak et al. (2016)	Smart city as a interconnected area		
Nærland et al. (2017), Du et al. (2018)	Smart contract conclusion through internet		
Lundin et al. (2017)	Smart trash bin connected via internet		
Fleisch et al. (2007)	Smart things communicating with the internet		
Bilstein & Stummer (2020)	Smart services connecting local customers, inner-city retailers and inner-city stakeholders		
Teubner and Stockhinger (2020)	smart products being connected via global telecommunication infrastructures		
Beverungen et al. (2019)	Smart products enhanced with connectivity		
March and Scudder (2017)	Smart products being ubiquitously wirelessly connected		
Corbett et al. (2017)	Wastewater management system connected with sensors	Short-Distance	
Hung et al. (2016)	Smart toy connected to other toys and services through networks		

Ma et al. (2017)	Bluetooth-connection between Smart Shirt and smartphone		
Alsaqer and Hilton (2015), Provost et al. (2015)	connection between geofence and elderly persons smartphone		
Häckel et al. (2019)	Cyber-physical systems communicating over the IoT		
Falan et al. (2011)	External microscope connected with a smartphone		
Oberländer et al. (2018)	Smart things communicating with nearby smart things		
Chasin et al. (2020)	Smart energy platform containing connectivity components		
Son et al. (2020)	Bluetooth-connection between asthma inhaler and smartphone		
Valogianni et al. (2014)	connectivity being crucial for smart home technologies		
Ma et al. (2017)	ECG sensors	Physical Sensors	Perception
van Putten et al. (2011)	Dishwasher condition sensors		
Warkentin et al. (2017)	Electricity grid sensors		
Novales et al. (2016), Cu et al. (2017)	Rain-sensors		
Bomhard and Wörner (2016), Cu et al. (2017)	Temperature Sensors		
Püschel et al. (2016)	Smart Security Camera		
Alsaqer and Hilton (2015)	GPS sensor		
Cu et al. (2017)	Wind sensor		
Cu et al. (2017)	Air humidity sensors		
Cu et al. (2017)	Light sensors		
Cu et al. (2017)	Soil humidity sensor		
Slavova et al. (2017), Kranz et al. (2010), Becker & Paukstadt (2021)	Smart meter sensor		
Corbett et al. (2017)	Water overflow sensors		
Corbett et al. (2017)	Underwater microorganism detector		
Hung et al. (2016)	smart toy sensory technologies		
Falan et al. (2011)	External microscope		
Lundin et al. (2017)	Trash filling level sensors		
Song et al. (2017)	location sensors		
Teubner and Stockhinger (2020), Porter	remote capture of physical data		

and Heppelmann (2014)			
Weber et al. (2017)	Sensing features embedded in physical things		
Benbunan-Fich (2019)	Smart devices collecting physical data		
Beverungen et al. (2019)	Smart products being equipped with sensors		
Püschel et al. (2016), Ma et al. (2017)	Smartphone call receiver	Digital Sensors	
Püschel et al. (2016), Alsaqer and Hilton (2015), Cu et al. (2017)	Text message receiver		
Holland et al. (2004)	Web crawler		
Brandt et al. (2017), Fleisch et al. (2007), Köpp et al. (2013), Flath et al. (2012)	Digitally transmitted information receiver		
Nærland et al. (2017), Du et al. (2018)	Smart contract information receiver		
Trunk et al. (2020)	perception as a necessary function for AI to work with foresight		
Song et al. (2017)	Virtual sensors (e.g., social media platforms)		
Newell and Marabelli (2014)	Sensing digital trails from social software applications		
van Putten et al. (2011), Slavova et al. (2017), Kranz et al. (2010), Loock et al. (2013)	Eyes	Human Receptors	
Bomhard and Wörner (2016)	Temperature receptors		
Püschel et al. (2016), Alsaqer and Hilton (2015), Cu et al. (2017)	Ears		
Ma et al. (2017)	Heart rate data interpretation	Algorithms	Interpretation
van Putten et al. (2011)	Dishwasher broken component analysis		
Novales et al. (2016)	Software running on microprocessors		
Bomhard and Wörner (2016)	Home Owner's Distance and in-home temperature data interpretation		
Alsaqer and Hilton (2015)	Location data interpretation		
Cu et al. (2017)	Compute optimal irrigation schedule		
Brandt et al. (2017), Flath et al. (2012)	Household power demand data interpretation		
Corbett et al. (2017)	Water quality data interpretation		
Fernando et al. (2016), Wastell et al. (2006), Valogianni et al. (2014)	Anticipation of smart home resident's needs		
Köpp et al. (2013), Becker & Paukstadt (2021)	Energy price interpretation		

Oberländer et al. (2018)	Autonomous data analysis		
Falan et al. (2011)	Analytics of mobile data		
Baird and Riggins (2016)	Analysis of environmental information		
Klötzer and Pflaum (2017)	Processing of information and data		
Lundin et al. (2017)	Analytics of trash filling level		
Trunk et al. (2020)	interpretation as a necessary function for AI to work with foresight		
Son et al. (2020)	Smart asthma management system analyzing patients inhaling behaviour		
Alter (2019)	smart things performing automated information processing		
Fischer et al. (2020)	Smart services provider interpreting customer data		
Warkentin et al. (2017)	Electricity grid data interpretation	Brain	
Bomhard and Wörner (2016)	Temperature data interpretation		
Slavova et al. (2017), Kranz et al. (2010)	LED color interpretation		
Loock et al. (2013)	Human being interpreting energy data		
Ma et al. (2017)	Decision on calling emergency at critical heart rate data	Algorithms	Decision
Novales et al. (2016), Weber (2017)	Autonomy embedded in smart products		
Novales et al. (2016)	Reactivity embedded in smart products		
Bomhard and Wörner (2016)	Decision on temperature adaption based on Home Owner's Distance		
Alsaqer and Hilton (2015)	Decision on navigation proposals		
Cu et al. (2017)	Decision on initiating irrigation		
Brandt et al. (2017), Flath et al. (2012)	Decision on charging point of time of Electric Vehicle		
Corbett et al. (2017)	Decision on autonomous diversion of wastewater		
Brauer and Kolbe (2016), Brauer et al. (2015)	Control of a smart city through pervasive computing		
Köpp et al. (2013)	Decision on energy load change		
Oberländer et al. (2018)	Independent decision making		
Becker & Paukstadt (2021)	Decision on optimization of energy management		
Bichler et al. (2010)	Smart market agents deciding independently on buying and selling		

van Putten et al. (2011)	Decision on contacting Manufacturer to order dishwasher spare parts	Brain	
Bomhard and Wörner (2016)	Decision on temperature adaption		
Lundin et al. (2017)	Decision on trash emptying		
Loock et al. (2013)	Human being deciding on energy usage behavior change		
van Putten et al. (2011)	Spare dishwasher part shipment	Physical Reaction	Behavioral Response
Warkentin et al. (2017)	Adapting power consumption		
Bomhard and Wörner (2016)	Adapting Temperature		
Püschel et al. (2016)	Audible Signal		
Püschel et al. (2016)	Vibration		
Brandt et al. (2017), Flath et al. (2012)	Charging of Electric Vehicle		
Slavova et al. (2017), Kranz et al. (2010)	Changing energy consumption behaviour		
Fleisch et al. (2007)	Grill weather report on bread		
Corbett et al. (2017)	Automatical diversion of waste water		
Fernando et al. (2016), Wastell et al. (2006), Valogianni et al. (2014)	Responding to smart home resident's needs		
Köpp et al. (2013)	Energy load change		
Becker & Paukstadt (2021)	Optimizing energy management		
Lundin et al. (2017)	Trash emptying		
Alter (2019)	Smart things performing physical actions		
Ma et al. (2017)	Phone call	Digital Reaction	
Püschel et al. (2016)	Text message		
Alsaqer and Hilton (2015)	Digital Navigation Proposals		
Cu et al. (2017)	Digital Irrigation Schedule Transmission		
Baird and Riggins (2016)	Autonomously sending request to change the state of other connected devices		
Kang et al. (2020)	smart technologies providing responsive support		
Cu et al. (2017)	Smart streetlights delivering personalized smart content		
van Putten et al. (2011)	Digital Product Memory	Data Storage	Organized Knowledge
Warkentin et al. (2017)	Electricity grid data storage		

Bomhard and Wörner (2016)	Temperature data storage		
Alsaqer and Hilton (2015)	Location data storage		
Cu et al. (2017)	Historical Soil data storage		
Holland et al. (2004)	Digital translation memory		
Brandt et al. (2017), Flath et al. (2012)	Historical Charging Behavior		
Slavova et al. (2017), Kranz et al. (2010)	Smart meter data storage		
Corbett et al. (2017)	Historical water overflow data		
Ziekow and Strueker (2011)	Storage with smart object data		
Köpp et al. (2013)	Historical energy prices		
Song et al. (2017)	data being stored and analyzed in the cloud		
Alter (2019)	Smart thing storing information in a database		
Bomhard and Wörner (2016)	Historical comfort temperature	Memory	
Slavova et al. (2017)	Memory on price signal LED colors		
Loock et al. (2013)	human being storing energy usage behavior		
Alsaqer and Hilton (2015)	Navigation Proposal Learning based on user navigation selection	Basic Learning	Learning
Kaldewei and Stummer (2018)	Smart products learning user predilections		
Alter (2019)	Smart things performing some degree of learning and adaptation		
Bichler et al. (2010)	Smart Market agents learning user preferences		
Fischer et al. (2020)	Smart thermostat learning residents' temperature preferences		
Püschel et al. (2016)	Smart products learning based upon data		
Brandt et al. (2017), Flath et al. (2012)	Charging behaviour learning based on household power consumption	Advanced Learning	
Köpp et al. (2013)	Power grid loading behavior learning based on energy price developments		
Becker & Paukstadt (2021)	Self-learning autonomous systems optimizing energy consumption		
Trunk et al. (2020)	Smart manufacturing technologies optimizing production planning based on machine learning algorithms		
Baptista et al. (2020)	Smart sensing technologies using self-		

	learning algorithms		
Beverungen et al. (2019)	Machine learning algorithms embedded in smart products		
Bichler et al. (2010)	Machine learning algorithms creating insights into existing and future smart markets		
Ma et al. (2017)	Heart rate data	Physical	Input
van Putten et al. (2017)	Dishwasher comonent data		
Warkentin et al. (2017), Becker & Paukstadt (2021), Ketter et al. (2016)	Electricity data		
Bomhard and Wörner (2016), Slavova et al. (2017)	Temperature data		
Püschel et al. (2016)	Physical movements		
Alsaqer et al. (2015), Casillo et al. (2017)	GPS data		
Cu et al. (2017)	Environmental soil data		
Slavova et al. (2017)	LED lights		
Corbett et al. (2017), Kranz et al. (2010)	Water overflow		
Köpp et al. (2013)	Energy prices		
Lundin et al. (2017)	Trash bin weight		
Berger et al. (2018), Berger et al. (2019)	human input information being transformed into electronic signals		
Runde und Faulkner (2019)	Input via keyboard or speech-recognition		
Püschel et al. (2016), Kalgotra et al. (2017)	Text message	Digital	
Holland et al. (2004), Cu et al. (2017)	Change on a website		
Brandt et al. (2017)	Information on power household demand		
Fleisch et al. (2007), Flath et al. (2012)	Weather report		
Falan et al. (2011)	Data from customer's quality complaint and internal defect cost controlling		
Olsen and Tomlin (2020)	Smart contracts being automatically triggered by external events		
Ma et al. (2017)	ECG patient's health monitoring	Physical	Output
van Putten et al. (2017)	Efficient dishwasher repairing		
Warkentin et al. (2017), Ketter et al. (2016	Power production efficiency increase		
Bomhard and Wörner (2016)	Efficient room temperature monitoring		

Cu et al. (2017)	Optimal farm irrigation		
Brandt et al. (2017)	Efficient electric vehicle charging		
Slavova et al. (2017), Flath et al. (2012)	Changes in power consumption behaviour		
Fleisch et al. (2007), Kranz et al. (2010)	Weather report on bread		
Corbett et al. (2017)	Efficient wastewater management		
Köpp et al. (2013), Becker & Paukstadt (2021)	Efficient energy load management		
Lundin et al. (2017)	Trash emptying		
Berger et al. (2018), Berger et al. (2019)	Smart things providing physical output such as visualization, acoustics, or motion		
Püschel et al. (2016)	Text message	Digital	
Alsaqer et al. (2015), Cu et al. (2017)	Navigation proposals		
Nærland et al. (2017), Du et al. (2018)	Smart contract conclusion		
Son et al. (2020)	Asthma management advisory		
Bomhard and Wörner (2016), Weber (2017), Casillo et al. (2017)	Environmental temperature change	Physical	Environment
Cu et al. (2017)	Soil quality change		
Fleisch et al. (2007), Kranz et al. (2010), Novales et al. (2016)	Weather change		
Corbett et al. (2017)	Waterflow change		
Klötzer and Pflaum (2017)	Smart products interacting with the environment		
Lundin et al. (2017)	Trash filling level change		
Chasin et al. (2020)	Smart energy products interacting with the physical environment		
Teubner and Stockhinger (2020), Porter and Heppelmann (2014)	smart connected products generating data about the physical environment		
Beverungen et al. (2019)	Smart products being part of an IoT-environment		
Brandt et al. (2017)	Household power demand change	Non-Physical	
Slavova et al. (2017), Flath et al. (2012), Köpp et al. (2013), Becker & Paukstadt (2021)	Energy price change		
Baird and Riggins (2016)	State of other smart devices		
Murphy et al. (2008)	Changes in the environment of the assets being managed		

Kaldewei and Stummer (2018)	smart products reacting proactively to environmental changes		
Oberländer et al. (2018)	smart things extracting information from the environment		
Song et al. (2017)	changes in enterprise statuses		
Bichler et al. (2010)	Smart market agents acting in trading environments		
Wastell et al. (2006)	Smart home as an electronic nervous system	Single System	System
Fernando et al. (2016), Kuebel et al. (2015)	Smart home ecosystem		
Ma et al. (2017)	Smart shirt, patient and hospital building a system		
Fernando et al. (2016)	Interrelated networks of actors (occupants, health care providers, care givers)		
Bomhard and Wörner (2016)	Residence owner, smart heating IS, and residence building a system		
Ma et al. (2017)	Heart disease patient and smart shirt building a system		
Alsaqer et al. (2015)	Elderly person, geofence and indirect wayfinding system building a system		
Häckel et al. (2019)	Suppliers, customers, vendors, and production infrastructure building an IT-dependent, intercompany smart factory network with complex interdependencies		
Niemimaa (2016)	Smart infrastructure including IT technologies, sensors, and other IT-based technologies		
Son et al. (2020)	Smart inhaler, asthma patient, and analytics tool building a system		
Cu et al. (2017)	Smart irrigation system, farmer and farm building a system and interacting with environmental systems	System of Systems	
Vervest et al. (2004)	Business operating system interacting with other business systems		
Fleisch et al. (2007), Kranz et al. (2010),	Smart toaster, bread and consumer building a system and interacting with environmental systems		
Slavova et al. (2017), Becker & Paukstadt (2021), Kranz and Picot (2012)	Smart meter, electricity grid and energy consumer interacting with external systems		
Brandt et al. (2017), Flath et al. (2012)	Smart charging system, electric vehicle and vehicle owner interacting with external energy systems		

Corbett et al. (2017)	Waste water management system, waste water plant and citizens interacting with external systems		
Baird and Riggins (2016)	Intelligent systems linking components and other systems		
Koo et al. (2013)	Smart tourism system consisting of user, web service, smartphone application and social network services		
Niemimaa (2016)	massive and complex interconnected systems		
Bilstein & Stummer (2020)	smart products operating within large ecosystems		
Lee et al. (2020)	smart system interconnected with the wearable device, a mobile app, data exchange, and analytics algorithms		
Baird and Riggins (2016)	Smart home devices being connected with each other or with other IT devices		

Appendix E

Appendix E provides an example of the building process from the initial text passages of the literature review to 1st order concepts via 2nd order themes to the final aggregate dimension (here: “subject”). As illustrated in Figure A2, we found text passages in the literature that described the application of smart technologies in different contexts. As we were interested in how smartness takes place and which actors are involved, we extracted different actors from literature that are involved in interactions with smart technologies and identified roles that those actors played in the interaction. Hence, we extracted actors such as a smart shirt (Ma et al., 2017) or a smart home system (Fernando et al., 2016) that performed different tasks. We identified that they can be grouped as smart things and that they both independently perform actions (autonomously calling the hospital; performing automatic resident adaptions). Consequently, we derived the 2nd order theme “Acting Smart Thing”. At the same time, we extracted actors, such as resident owners (Bomhard & Wörner, 2016) or farmers (Cu et al., 2017) that were involved in applications of smart technologies. Here, we identified that those actors are both individuals and perform actions based on recommendations of smart technologies. We derived that individuals are involved in interactions with smart technologies and categorized them as “Acting Individuals”. Theoretical sensitivity in mind, we compared the identified 2nd order themes with existing theoretical concepts and summarized them as “Subjects”, based on the existing theoretical concept “Subject” from Activity Theory. In doing so, we searched for theories that involve acting capabilities and explain the role of different actors within technology-related interactions (Engeström, 1987). Herein, Activity Theory is a well-established theory for explaining acting capabilities and has been used within IS research for building and explaining interactions (Benbunan-Fich, 2019).

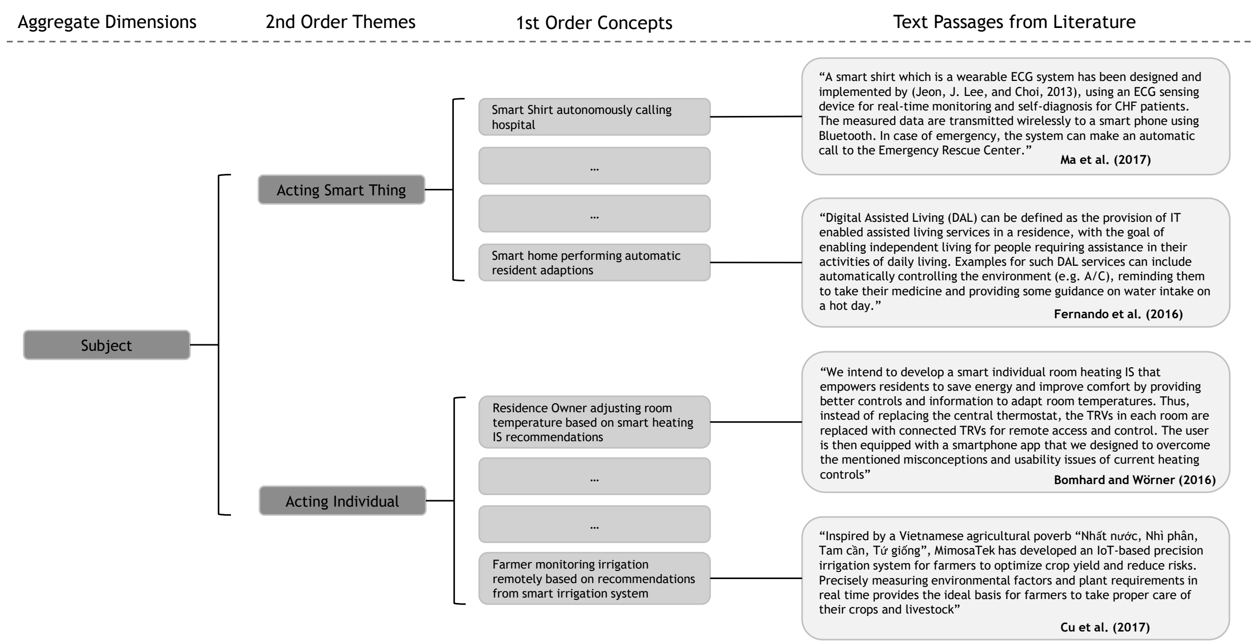

Figure E1. Exemplified Aggregate Dimension Building Process

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