

# Value Co-Creation in Smart Services: A Functional Affordances Perspective on Smart Personal Assistants

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## Abstract

In the realm of smart services, smart personal assistants (SPAs) have become a popular medium for value co-creation between service providers and users. The market success of SPAs is largely based on their innovative material properties, such as natural language user interfaces, machine learning-powered request handling and service provision, and anthropomorphism. In different combinations, these properties offer users entirely new ways to intuitively and interactively achieve their goals and thus co-create value with service providers. But how does the nature of the SPA shape value co-creation processes? In this paper, we look through a functional affordances lens to theorize about the effects of different types of SPAs (i.e., with different combinations of material properties) on users' value co-creation processes. Specifically, we collected SPAs from research and practice by reviewing scientific literature and web resources, developed a taxonomy of SPAs' material properties, and performed a cluster analysis to group SPAs of a similar nature. We then derived 2 general and 11 cluster-specific propositions on how different material properties of SPAs can yield different affordances for value co-creation. With our work, we point out that smart services require researchers and practitioners to fundamentally rethink value co-creation as well as revise affordances theory to address the dynamic nature of smart technology as a service counterpart.

**Keywords:** Smart Personal Assistants, Value Co-Creation, Smart Services, Affordances

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## 1 Introduction

Driven by the proliferation of information technology (IT), smart services that rely on smart technical objects produce profound changes in customer experience and value co-creation (Ostrom et al., 2015; Leimeister, 2020). These *smart technical objects* (STOs) combine contemporary technologies—such as natural language processing, machine learning, and context-sensitive autonomous behavior—and are often used for smart

service provision (Beverungen et al., 2019; Medina-Borja, 2015). One prominent type of STO is a *smart personal assistant* (SPA), also referred to as a conversational agent or intelligent agent. An SPA “uses inputs such as the user’s voice, vision (images), and contextual information to provide assistance by answering questions in natural language, making recommendations, and performing actions” (Hauswald et al., 2016, p. 2). Hence, SPAs offer entirely new ways for engaging users through innovative interaction possibilities to co-create value between service

providers and potential customers. In this context, commercial SPAs—such as Amazon’s Alexa-powered Echo products and Google’s home pods running Google Assistant—have recently enjoyed much market success (Tractica, 2016).

However, while more and more companies are relying on SPAs for smart service provision, neither research nor practice has a clear understanding of how the nature of these systems shapes value co-creation processes. From an information systems (IS) research perspective, predominant theories often view technology as static and reactive artifacts—things that users interact with to achieve their goals by appropriating the technology’s characteristics and, as time passes, finding better or even entirely new ways to co-create value (Benlian, 2015; Schmitz et al., 2016; Sun, 2012). However, in the realm of smart technology, one may question whether this view is still valid. In contrast, we might assume that smart services require an understanding of technology that, based on context and usage information, proactively and dynamically shapes affordances offered to users. From this point of view, existing theories should be revised in order to take such an understanding into account. From a practical perspective, both service providers and users usually pick popular SPAs, such as Amazon’s Echo products, without assessing the fit with their goals and the value they desire. This is a major problem because the value of services can only be leveraged if the intended user group uses the services (Chandler & Vargo, 2011; Grönroos, 2008, 2011; Vargo, 2008; Vargo et al., 2008).

Our paper addresses these challenges by theorizing on value co-creation with SPAs based on functional affordances theory. We first identify SPA implementations and follow the approach introduced by Nickerson et al. (2013) to develop a taxonomy of SPAs’ material properties. This taxonomy represents the “lowest common denominator” of material properties with sufficient variance for the differentiation and grouping of objects. Using functional affordances as a theoretical lens, we posit that the co-creation of value in the interaction between users and an SPA depends on the material properties (or features) of the SPA as well as on what affordances these material properties provide for the user. After grouping SPAs with similar material properties using cluster analysis, we derive theoretical propositions for each group about how SPAs affect value co-creation. The functional affordances can then guide practitioners in choosing the type of SPA whose affordances best match the needs of a specified user or user group. Consequently, our study takes a properties-affordances view on value co-creation in smart services by addressing the following questions: *What are the material properties of SPAs? How can SPAs be grouped according to similar material properties?*

*What can be inferred about the affordances of each group and their effects on value co-creation?*

Our results contribute to theory by providing a taxonomy of SPAs that can serve as the foundation for the subsequent development of suitable smart services. Furthermore, we propose how each type of SPA may influence value co-creation with users in smart services. For practitioners interested in leveraging the potential of an existing SPA for their business, we provide the basis to make an informed choice of an SPA for their particular goal. For practitioners interested in developing a novel SPA, we help identify the type of SPA that might be best suited for a certain purpose and offer corresponding design implications for different SPA characteristics.

The remainder of the paper is structured as follows. In Section 2, we introduce the concept of value co-creation in the realm of smart services and we introduce functional affordances theory. In Section 3, we identify, structure, and group material properties of SPAs. Based on this structure, in Section 4, we establish theoretical propositions on value co-creation in smart services for each cluster. The outcomes of the theory development are discussed in Section 5, in terms of theoretical and practical contributions as well as limitations of this study and possible future research. We conclude with a short summary in Section 6.

## 2 Theoretical Foundation

### 2.1 Value Co-Creation in Smart Services

We seem to be reaching the tipping point in an era of “smart everything,” where smart services dominate numerous areas of industrialized economies (Medina-Borja, 2015). As opposed to our understanding of “traditional” services as human-centered processes in which value is co-created by the interaction of two or more actors (individuals, organizations, or public authorities), the notion of *smart services* shifts the focus toward value creation between humans and sophisticated—i.e., smart—technical objects (Maglio, 2015; Medina-Borja, 2015; National Science Foundation, 2014). In IS, “smart” often refers to a list of potential characteristics of a system interacting with humans, such as learning, contextual adaptation, data-driven decision-making or “self-” abilities, including self-regulation, self-learning, self-awareness, self-organization, self-creation, self-management, and self-description (Beverungen et al., 2019). All these characteristics indicate that STOs should be understood as—to certain degrees—autonomous, reflective, and cognitively advanced service counterparts for human users.

Considering these attributes, one might assume differences in the way value is created in smart services. In the traditional service-dominant logic

stream of service science literature (Vargo & Akaka, 2009; Vargo & Lusch, 2008, 2014), both customers and organizations are seen as co-producers (Vargo & Lusch, 2004) or co-creators (Vargo & Lusch, 2008) of value. This view implies that single actors cannot create value for other actors by themselves but rather “can make offers that have potential value” (Vargo & Lusch, 2011, p. 185). Thus, “value is always uniquely and both experientially and contextually perceived and determined by the customer” and “is accumulating throughout the customer’s value-creating process” (Grönroos, 2011, p. 293). While smart service providers generally capture value monetarily (also via user data, payments, and advertising), consumers may view value as functional (i.e., by helping to accomplish certain tasks), hedonic (i.e., by creating joyful experiences), social (i.e., by facilitating a sense of community), or some combination of the above (Paukstadt et al., 2019). The joint effort of different stakeholders and technology to co-create a mutually valued outcome is the core purpose and central process in economic exchange and, consequently, a major attribute of smart service systems (Lim & Maglio, 2018). Grönroos (2011) explicitly differentiates between value creation of the user as value in use versus value creation as an all-encompassing process including value for the user and (financial) value for the firm. While it is among the most ill-defined and elusively used concepts (for different interpretations of value and value creation, see Grönroos, 2011, pp. 281-282), *value co-creation* generally means a process of interaction between a service consumer and a service provider that increases the user’s well-being or aids the user in some respect (Grönroos, 2008, 2011; Vargo, 2008).

The purpose of this paper is to make propositions on how and why STOs such as SPAs affect the value co-creation of consumers. Based on the aforementioned definitions and our purpose in this study, we define *value co-creation in smart services* as a process in which, through or with the help of STOs, service consumers and service providers jointly produce an outcome that is perceived as valuable by individual service consumers with respect to their context and prior experience. This definition emphasizes a consumer-centric view of value co-creation, which is, indeed, the predominant perspective in this paper.

## 2.2 Smart Technical Objects and Smart Personal Assistants

Technical objects that facilitate value co-creation between service providers and service consumers are omnipresent. Prior studies have specified technical objects as boundary objects that bridge gaps between entities in a service system by integrating subprocesses and resources to enable value co-creation (Becker et al., 2012). The material properties

of recent STOs—such as identification, localizing, connectivity, sensors, storage and computation, actuators, interfaces, and visibility (Beverungen et al., 2019)—allow them to act as both resource integrators and as (semi)autonomous service providers in smart service systems (for various definitions and a unified understanding of smart service systems, see Lim & Maglio, 2018). Consequently, value co-creation between service providers and service consumers in smart service systems depends to a great extent on the material properties of the STO, which determine the set of possible actions available in STO-mediated interactions.

Over the last few years, task assistance in particular has been enhanced by the use of STOs. SPAs are STOs that use “inputs such as the user’s voice, vision (images), and contextual information to provide assistance by answering questions in natural language, making recommendations, and performing actions” (Hauswald et al., 2016, p. 2). SPAs originate from early question-answering systems such as BASEBALL (Green Jr. et al., 1961), ELIZA (Weizenbaum, 1966), and LUNAR (Woods & Kaplan, 1977) that marked the first steps in the field of artificial intelligence to support experts in specific but relatively limited knowledge domains (Kincaid & Pollock, 2017). In contrast, today’s SPAs (such as Alexa, Siri, and Google Assistant devices) benefit from the rapid technological developments of the past few years, including infrastructure scalability, natural language processing, and semantic reasoning. These allow SPAs to interact with users in a more natural manner while offering many opportunities for value co-creation, i.e., to provide information and services that help users to reduce the effort and complexity of task accomplishment (Cowan et al., 2017; Winkler & Söllner, 2018).

The novelty of SPAs lies in two major aspects: the various possibilities for users to interact with the device as well as the knowledgeability and human-like behavior of the intelligent agent (Maedche et al., 2016; Morana et al., 2019). Compared to other classes of technical objects where users are obliged to learn commands that are specified in a given syntax to instruct the system, SPAs afford communication in ways that feel more natural, like writing and talking in natural language or pointing at things. Prior work regarding the SPA as a technical object includes the development and evaluation of SPAs and SPA components as commonly found in the human-computer interaction and computer science disciplines (e.g., Armentano et al., 2006; Cassell, 2000; Derrick et al., 2011; Griol et al., 2013; Kanaoka & Mutlu, 2015), the effect of personification and human-like traits on user satisfaction (Cowan et al., 2017; Luger & Sellen, 2016; Purington et al., 2017), emotional responses toward SPAs (Sandbank et al., 2017; Yang

et al., 2017), as well as security, privacy, and trust of and in SPAs (Campagna et al., 2017; Mihale-Wilson et al., 2017; Nasirian et al., 2017; Zierau et al., 2020).

Since one major goal of this paper is to identify and structure material properties of SPAs, prior structuration approaches guide our work. Maedche et al. (2016) categorize assistive technology into four types according to their degree of intelligence and interaction: basic user assistance systems, interactive user assistance systems, intelligent user assistance systems, and anticipating user assistance systems. Our taxonomy follows this notion by distinguishing between material properties that relate to the interaction possibilities between users and SPA devices (e.g., Amazon Echo) and to the intelligence of the agent (e.g., Alexa), referring to information capture, processing, and retrieval capabilities. Purington et al. (2017) highlight the importance of personification and integration with other network resources. We therefore attribute social representation and external control abilities to our initial conceptualization. Finally, Jalaliniya and Pederson (2015) describe four different information exchange mechanisms between SPAs and users, namely implicit and explicit input and output. To take this typology into account, our initial conceptualization of material properties considers various modes and directions of interaction. Based on this prior work, we identify and structure the material properties of SPAs and establish theoretical propositions on how these afford value co-creation between service providers and consumers.

### 2.3 Functional Affordances

Rooted in ecological psychology, the concept of *affordances* was introduced by Gibson (1986) as a theory that links the perception of inherent values and meanings of certain things in the environment to possible actions available to an organism (Benbunan-Fich, 2018; Şahin et al., 2007). In the context of our study, this refers to how users perceive values and meanings of SPA properties and how these perceptions are linked to possible user actions. This implies that SPA users must have a certain perception of the SPA and what it is good for before interacting with it (Leonardi, 2011).

While the original concept of affordances stems from psychology and has received notable attention across psychology subfields, scholars from a wide range of other disciplines have also adopted it to their research contexts (cf. for an overview Şahin et al., 2007). When considering the impact of affordances for technology, human-computer interaction research introduced the concept to the design of objects (Norman, 1988) and explained how affordances influence the use of IT artifacts (Norman, 1999). In Norman's (1988) original interpretation, affordances are certain properties of an IT artifact that manifest through design decisions (e.g., user

interface design), suggesting, in turn, possible functionalities that could be triggered by users. This interpretation neglects the original organism-environment relationship and emphasizes the designed-in affordances of technology (Benbunan-Fich, 2018). In addition, Norman (1999) later also introduced a distinction between real affordances, which relate to physical characteristics of an IT artifact and are related to its operations (e.g., the keyboard of a personal computer), and perceived affordances, which relate to the appearance of an IT artifact (e.g., the user interface) and suggest the proper operation.

Today, the affordance concept is widely used in IS research to analyze IT artifacts and their potential effects (cf. the following reviews concerning an overview of the affordance concept in IS research: Pozzi et al., 2014; Stendal et al., 2016; Wang et al., 2018). Some studies analyze technologies at a broad level: e.g., concerning their perceived usefulness as an instrumental technology outcome (Grgecic et al., 2015). However, analyzing the affordances of a single technology is particularly useful for providing rich information to describe an emergent technology-in-use (Benbunan-Fich, 2018; Lindberg et al., 2014). This is especially true when understanding innovation processes and their outcomes in complex and dynamic service systems (Nambisan et al., 2017) as well as co-creation in digital markets (Lang et al., 2015). In this context, Barann (2018) investigates how retail processes are shaped through affordances when, for example, STOs are evaluated as digital touchpoints. When considering STOs used as personal devices (for example, wearables such as activity trackers), affordances also serve as a framework to understand user interaction and outcomes for emergent technologies that are used in novel contexts (Lankton et al., 2015). Lankton et al. (2015) also investigated how affordances relate to trust for different IT artifacts and suggested that social affordances from SPAs, such as voice features, contribute to shaping user perceptions, e.g., concerning technology's humanness. Finally, the affordance view has also been applied to SPAs, in the context of health environments, for example, to understand what different types of affordances emerge during use processes (Moussawi, 2018). Therefore, the affordance lens is ideal for studying and understanding the effects of SPAs as STOs on value co-creation in smart services. This perspective has, to date, been missing in the literature. Indeed, we take the affordance perspective one step further and examine the effects of SPAs using the narrower concept of functional affordances.

The concept of functional affordances proposed by Markus and Silver (2008) allows for a more feature-centric view of STOs, while at the same time overcoming limitations of adaptive structuration theory (especially concerning the concepts of structural features and spirit as proposed by DeSanctis et al.,

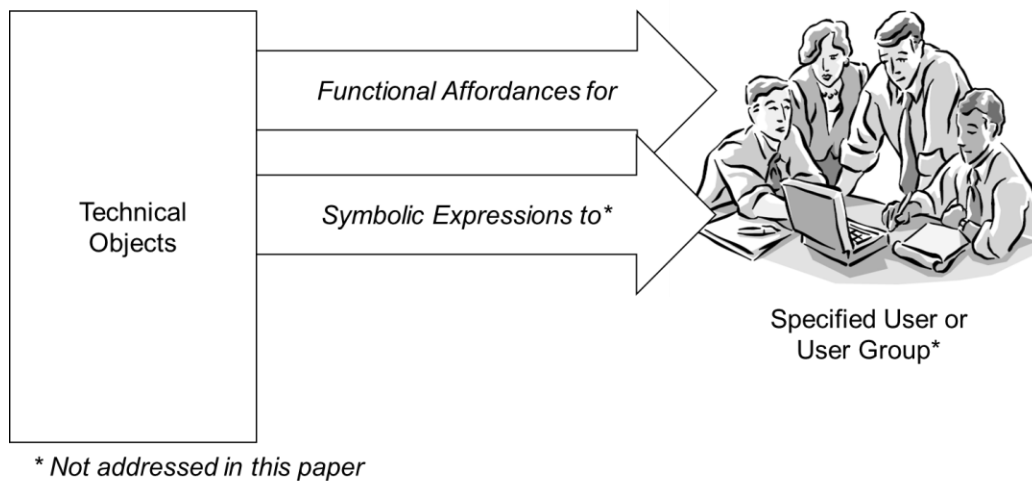


2008), and is also advantageous compared to other feature-centric theories (e.g., Benlian, 2015) that focus solely on feature lists of a single IT artifact. Thus, affordances help us to generate more generalizable insights concerning the IT artifact under investigation. By also considering how IT artifacts not only enable user actions but also actively shape IT outcomes as individual “actors” (Markus & Silver, 2008),<sup>1</sup> explanations for the evolving and dynamic developments in smart services can be found.

*Functional affordances* are defined as “the possibilities for goal-oriented action afforded to specified user groups by technical objects” (Markus & Silver, 2008, p. 622). This definition highlights the concept of the technical object—in our case, an SPA—as it relates to the IT artifact and its components, including the user interface, while also taking into account the goals and actions of specific user groups. Referring to such user groups, functional affordances and the action possibilities they offer may vary depending on how the user group perceives the values and norms of the technical object. These communicated values and norms are also described as symbolic expressions (Markus & Silver, 2008) that are related to a technical object. However, considering the little current state of knowledge regarding value co-creation with STOs in smart services, we focus in this study on proposing the

effects of functional affordances on value co-creation and exclude the view on the link between technical objects and specific user groups, i.e., symbolic expressions, to handle the complexity of understanding functional affordances of SPAs. Figure 1 shows how functional affordances and symbolic expressions relate the technical object to specified user groups.

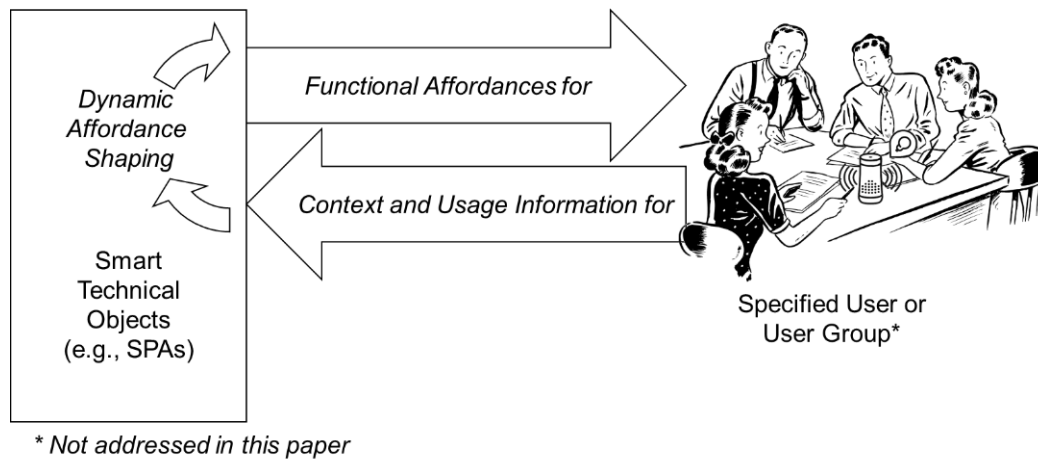
For smart services with SPAs, it is reasonable to assume that value co-creation is substantially influenced by the material properties of the SPA and, consequently, also by its affordances. Value is co-created by people interacting with SPAs in a certain way. This fact becomes even more interesting when one considers that the “smart characteristics” of the technical object—such as context sensitivity, self-control, and learning abilities—have the potential to provide affordances that are both dependent and individually tailored to users’ needs, contexts, and experiences. Therefore, research on smart services entails revising the understanding of a static technical object and replacing it with that of an STO (e.g., an SPA) that collects and analyzes context and usage information to dynamically shape affordances according to users’ needs and, consequently, be just as adaptive and changeable as its human counterparts in the smart service (Figure 2).



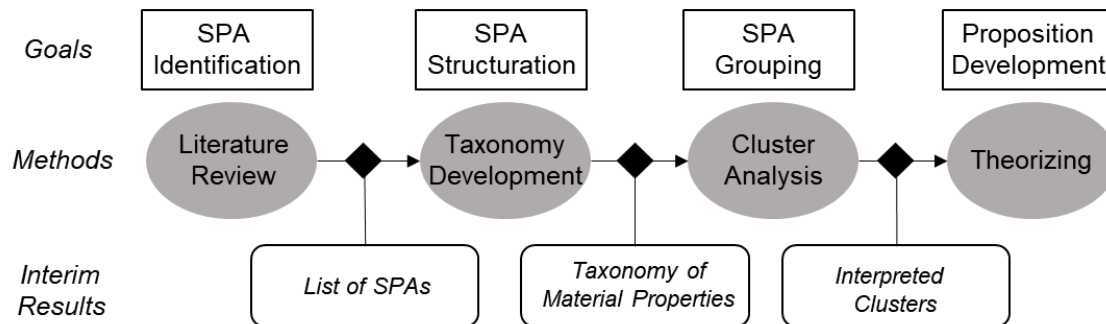
**Figure 1. The Relationship Between Technical Objects, Functional Affordances, Symbolic Expressions, and Specified User Groups (Markus & Silver, 2008, p. 624)**

<sup>1</sup> This is in contrast to theoretical views where IT outcomes are solely shaped by human agency. However, when considering evolving and dynamic IT artifacts that may also learn on their own through complex machine learning

algorithms, we assume that it is necessary to adopt a view that also takes this IT-centric perspective for understanding agency into account.



**Figure 2. The Relationship Between STOs, Functional Affordances, Context and Usage Information, and Specified User Groups (based on Markus & Silver, 2008, p. 624)**



**Figure 3. Research Goals, Methods, and Interim Results**

## 3 Material properties of Smart Personal Assistants

### 3.1 Methodology

In order to theorize about SPAs' functional affordances for value co-creation, we must first understand which material properties shape the nature of SPAs in smart services. Finding these material properties requires the "right" level of abstraction that allows for proposing both generalizable and operationalizable causal relations of the interaction between users and SPAs. Material properties collected from various technical objects may be too broad to operationalize derived propositions, while focusing on a few selected ones may result in too narrow a scope for generalization. We investigated SPAs as a class of STOs, which allowed us to formulate propositions based on material properties that are repetitive within the class of SPAs and, thus, are likely to have both explanatory power for smart services in general as well as operationalizability for other types of STOs.

To elucidate the nature of SPAs, their material properties, and structural differences, we conducted four steps to achieve four goals (Figure 3). First, we identified SPAs by conducting an open database literature review and an additional web search for commercial products that have not been extensively addressed in the scientific literature. Second, we extracted information to build a taxonomy of material properties following the iterative taxonomy development process proposed by Nickerson et al. (2013). Third, we performed a cluster analysis to identify groups of SPAs that are structurally similar, i.e., that share similar material properties. Fourth, using our descriptions of different types of SPAs, we theorized how ensembles of material properties shape value co-creation in smart services. In the following sections, we describe our procedure and the results for each step.

### 3.2 SPA Identification

To identify SPAs, we conducted a literature review (Cooper, 1988; vom Brocke et al., 2015; Webster &

Watson, 2002). We enriched the results of the literature review through an open web search for product descriptions and manuals that describe commercial SPAs that are not addressed in the scientific literature. Our goal was to find SPAs that fit the definition established by Hauswald et al. (2016, p. 2), which defines an SPA as a system that “uses inputs such as the user’s voice, vision (images), and contextual information to provide assistance by answering questions in natural language, making recommendations, and performing actions.”

The literature review aimed to identify papers that describe the material properties of SPAs in as completely as possible. As a result, papers that focus on technical details of only one or a few SPA features were excluded, as were papers that address SPAs in a too holistic and abstract way without addressing their material properties. Therefore, the literature review focused on SPAs as research outcomes and practical applications without taking a judgmental position. Both researchers investigating and practitioners working on and with SPAs may benefit from the literature review results because they shed light on the different material properties of a large and heterogeneous bandwidth of SPAs.

Study of extant literature (e.g., Maedche et al., 2016; Nunamaker et al., 2011; Purington et al., 2017; W. Wang & Benbasat, 2005) revealed the following keywords: “smart assistant,” “conversational agent,” “virtual assistant,” “assistance system,” and “personal assistant.” These keywords were used for an open database search of IS, human-computer interaction, and computer science literature. The search was constrained to the title, abstract, keywords, and a publication period from January 2000 to November 2018. Databases included AISEL, EBSCO Business Source Premier, ScienceDirect, IEEE Xplore, ACM DL, and ProQuest. The open database search resulted in 2802 hits. Titles, abstracts, and keywords were screened to fit the abovementioned SPA definition and the scope of our study. We excluded papers that did not refer to assistants as STOs, excluding papers that refer to assistants as static, context-insensitive technical objects, nontechnical assistants (e.g., human assistants), and assistive systems in a sociological or political manner (e.g., national social assistance systems). We also excluded technical and formal reports of basic technology (e.g., formal view on multilayer voice recognition models). All remaining papers describe the features of the respective SPA in parts or in their entirety. This screening process resulted in 354 potentially relevant papers. After a subsequent forward and backward search, which yielded three more relevant papers, we thoroughly read each paper and retained 91 papers that describe the material properties of 86 SPAs (a concept matrix including the classification of each SPA can be found in Table B5 in Appendix B). As the difference indicates, some SPAs were developed successively over time so that multiple publications

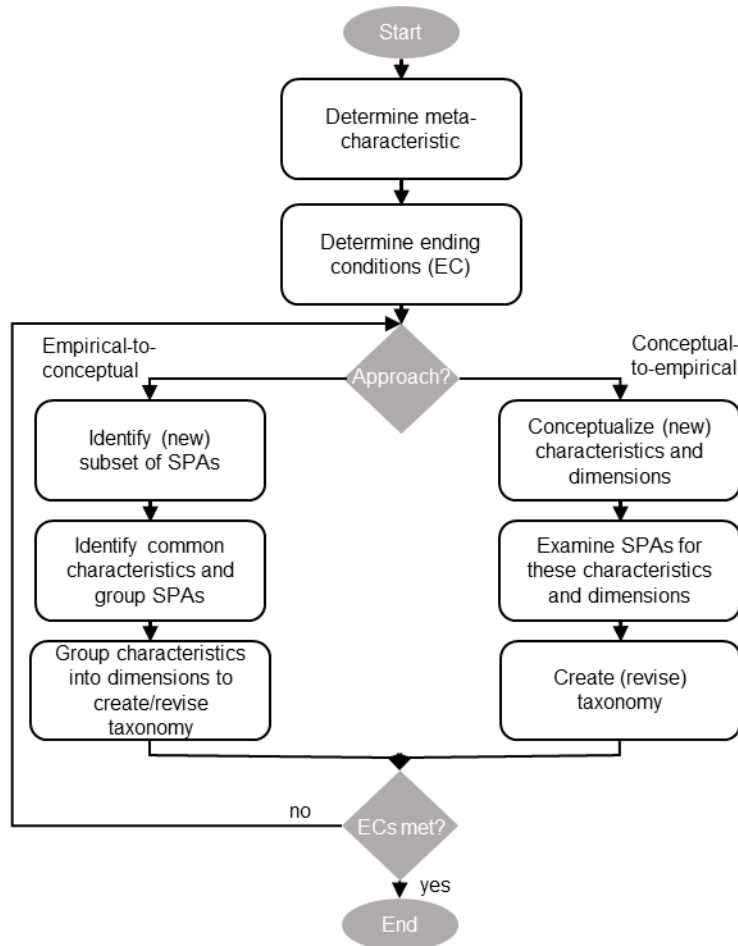
describe different material properties of one and the same SPA. These partial descriptions were consolidated in such a way that for each SPA in the sample, a holistic image was obtained that could be processed in the next steps.

To include well-known commercial SPAs in our sample, we conducted an open web search using the same goal and criteria as for scientific publications. The web search revealed information on 24 commercially developed SPAs. These objects not only enhanced the existing sample but also shed light on the status quo technology used for the broad consumer market. In contrast to the scientific literature, publicly available internet documents—be they from SPA providers or independent media—usually view the SPA holistically while highlighting the benefits and threats of certain features (such as voice recognition) for users. In all, a total of 110 SPAs were identified. Appendix A provides an overview of the results of the SPA identification phase.

### **3.3 SPA Structuration**

The next step was to identify and structure the material properties of the SPAs. For this purpose, we developed a taxonomy: a conceptualization of design knowledge that provides structure and organization, thus enabling researchers to study relationships among concepts and theorize about these relationships (Glass & Vessey, 1995; Iivari, 2007; McKnight & Chervany, 2001; Nickerson et al., 2013). Taxonomies have been developed for a wide variety of concepts in the IS domain, such as open source research (Aksulu & Wade, 2010), digital business models (Bock & Wiener, 2017), gamification (Schöbel & Janson, 2018; Schöbel et al., 2020), and motivations for system use (Lowry et al., 2015).

Taxonomies are important tools in many disciplines to structure and classify real-world objects of interest and allow for both analysis and theorization of complex domains (Bapna et al., 2004; Doty & Glick, 1994; Glass & Vessey, 1995; Miller & Roth, 1994). Since our goal is to establish propositions on how the nature of SPAs shape value co-creation, a taxonomy is helpful for understanding this nature in a way that allows for differentiation and classification. In particular, our taxonomy aims to shed light on the material properties of SPAs, how they relate to each other, and which ensembles of material properties are common. While prior work has mainly focused on describing different characteristics of SPAs, as described in the background section on STOs and SPAs, this has not yet been done in a way that allows for classification, identification of common configurations, and theorizing from a feature-level perspective, i.e., explicitly considering the material properties of SPAs.



**Figure 4. Taxonomy Development Process (based on Nickerson et al. 2013)**

Using the results of the object identification phase, we follow the iterative taxonomy development process introduced by Nickerson et al. (2013). Figure 4 shows this process. In accordance with this process, our first step was to define a metacharacteristic. The *metacharacteristic* is the most comprehensive characteristic; it reflects the purpose of the taxonomy and guides the choice of dimensions and characteristics for taxonomy development (Nickerson et al., 2013). Since our ultimate goal was to theorize on the interactional, feature-related value co-creation mechanisms of SPAs, we defined “material properties of SPAs from an interactional consumer perspective” as the metacharacteristic of our taxonomy. In particular, the taxonomy contains material properties that affect how users and SPAs interact to co-create value. To account for the nature of SPAs, we subdivided the taxonomy dimensions and the material properties into a superordinate *hardware dimension* and a superordinate *intelligent agent dimension*. While the hardware properties of an SPA describe the system’s possibilities to interact with the outside world, intelligent agent properties describe the system’s “cognitive” processes, such as sensemaking and learning, as well as how it presents itself to the

user. This division thus follows the basic sense of the distinction made by Maedche et al. (2016).

In the next step, to determine when to terminate the upcoming iterative process, we defined four ending conditions (ECs):

- All SPAs identified in the literature review have been examined.
- At least one object is classified under every characteristic of every dimension (i.e., no ‘null’ characteristics).
- No new dimensions or characteristics were added in the last iteration.
- Dimensions, characteristics, and cell combinations are unique and not repeated.

The researcher may then choose between two paths: the *conceptual-to-empirical (deductive) approach*, which requires screening of the objects according to prior conceptual or theoretical knowledge; or the *empirical-to-conceptual (inductive) approach*, which means to list properties of each object, group them, and develop dimensions and characteristics based on these groups. For the first iteration, we chose the conceptual-



to-empirical approach since knowledge on smart services already exists. Therefore, we established initial dimensions based on prior characterizations (see Section 2.2): communication mode, directionality, and integration as hardware dimensions, and representation as intelligent agent dimension (Jalaliniya & Pederson, 2015; Maedche et al., 2016; Purington et al., 2017). To derive the first characteristics, i.e., material properties, we referred to the conceptualization of smart product properties and their implications for smart services proposed by Beverungen et al. (2019). While these properties are generic to STOs (or “smart products,” as the authors call these types of systems), we used the aforementioned literature, which was selected based on our SPA definition, to derive implications for SPAs and to formulate the initial taxonomy characteristics. To the extent that common implications were derived for them, we combined properties that, according to the SPA definition and the metacharacteristic of our taxonomy, describe different perspectives of one and the same subject. In particular, the properties *localizing*, *invisible computers*, and *sensors* all describe how context data are collected to tailor services to the needs of users, thus enabling value co-creation possibilities. Likewise, the properties *connectivity*, *storage and computation*, and *actuators* describe the basic infrastructure (e.g., local databases, distributed resources, actuators) that is needed to control the external environment. Starting with existing knowledge about STOs, this process allowed us to formulate specific implications for SPAs and extract dimensions and characteristics for the first-iteration taxonomy. Table B1 (Appendix B) describes how we conceptually derived first-iteration characteristics.

In the subsequent four empirical-to-conceptual iterations, we inductively challenged the latest status

of the taxonomy by classifying convenience samples of SPAs and revising existing dimensions and characteristics accordingly. To achieve the goal of sufficient delimitation of all objects in the current iteration sample, we adapted dimensions and characteristics of the preceding iteration to account for the properties of the sample objects. For example, in the first empirical-to-conceptual iteration it became evident that a large number of objects could be assigned to the communication mode of *active interaction* although they often provide significantly different ways of communication. To account for these differences, we split the active interaction characteristic into text, voice, visual, and text and visual (and later also voice and visual) to more closely reflect the actual objects’ properties. We also added completely new dimensions with at least two characteristics each (often manifestations of a dichotomous property, e.g. external control and no external control) in case interaction-relevant properties accumulated that could not yet be addressed by the prevailing structure. The evolution of dimensions and characteristics according to the taxonomy development iteration is shown in Table B2 (Appendix B).

In total, we classified all of the 110 SPAs into five iterations until all ECs were met. Figure B1 (Appendix B) shows how the taxonomy evolved over the entire process. Also, Table B5 (Appendix B) shows a concept matrix with sources, taxonomy characteristics, and the final cluster for each of the 110 SPAs. Table 1 presents the final taxonomy of the material properties of the SPAs. The taxonomy consists of eight dimensions, each with two to six associated material properties. We discuss this in detail below, providing justificatory references for each material property.

**Table 1. Taxonomy of Material Properties of SPAs**

Dimensions		Material properties					
Hardware	<i>Communication mode</i>	text	voice	visual	text and visual	voice and visual	passive observation
	<i>Directionality</i>	unidirectional			bidirectional		
	<i>Integration</i>	no external control			external control		
Intelligent Agent	<i>Knowledge model</i>	specific			general		
	<i>Request complexity</i>	data		primitive natural language		compound natural language	
	<i>Adaptivity</i>	static behavior			adaptive behavior		
	<i>Collective intelligence</i>	no crowd data			crowd data		
	<i>Representation</i>	none	virtual character		artificial voice		virtual character with voice

### 3.3.1 Hardware Properties

Three dimensions exist to describe the interaction with the SPA hardware: communication mode, directionality, and integration.

**Communication mode** refers to the primary way(s) in which a user communicates with an SPA and vice-versa. Communication is either primarily text based (Sansonet et al., 2012), voice based (Weeratunga et al., 2015), visual sensor based (Jalaliniya & Pederson, 2015), text and vision based (Kincaid & Pollock, 2017), voice and vision based (Hauswald et al., 2016), or passively observational—i.e., the SPA assists by gathering context data without being consciously perceived by the user (Chen et al., 2014).

**Directionality** comprises unidirectional interaction (Campagna et al., 2017) and bidirectional interaction (Tsujino et al., 2013). Unidirectional interaction means that either the user or the SPA provides information that is intentionally directed toward the other but the recipient does not respond to the sender's request thereafter. Bidirectional means that the SPA co-creates value in communicational exchange.

**Integration** refers to an SPA's outreach to other smart things in the network or to the user's digital life through external control, e.g., concerning an ecosystem integration. One can broadly distinguish between SPAs with the ability to, for example, control smart household objects, post on social media, or shop on behalf of the user (Hauswald et al., 2016), and SPAs designed solely for question answering and information recall without external control (Sugawara et al., 2011). It is also possible for an SPA to have no external control because it operates in isolation from other systems (Graesser et al., 2005).

### 3.3.2 Intelligent Agent Properties

Five dimensions exist that describe the interaction with the intelligent agent of the SPA: knowledge model, request complexity, adaptivity, collective intelligence, and representation.

**Knowledge model** refers to an SPA's ability to answer questions and process requests. It determines the general ability to provide appropriate assistance (i.e., co-create value) to a user or user group in a given context. An SPA may either provide general (broad) assistance such as retrieving information, searching on the web, or playing one's favorite music (Sansonet et al., 2012), or specific (deep) assistance for certain complex tasks or to a dedicated user group (Kincaid & Pollock, 2017; Sugawara et al., 2011).

**Request complexity** describes an SPA's ability to dismantle and process user requests of different complexity levels. The simplest form is the processing of collected or manually entered data (Chen et al.,

2014), followed by simple natural language commands such as “send email to Jeff” (Weeratunga et al., 2015), followed by compound natural language commands, such as “every day at 6am get the latest weather and send it via email to Jeff” (Campagna et al., 2017).

**Adaptivity** refers to the system's ability to learn from (usually a large amount of) usage and context data and adapt accordingly in the future. Examples are the improvement of speech recognition (Arsikere & Garimella, 2017) or tailored interaction for different users in the same context (Armentano et al., 2006). An SPA is characterized to show either static behavior if the system's behavior and capabilities remain the same over the period of use (Grujic et al., 2009), or adaptive behavior if its performance improves according to context and use data (Campagna et al., 2017).

**Collective intelligence** is defined as the ability to learn, understand, and adapt to an environment by using the knowledge of the user crowd (Leimeister, 2010; Durward et al., 2020). SPAs may leverage the potential of collective intelligence to improve machine learning algorithms and thus increase the quality of their assistance (Dellermann et al., 2019). For example, the analysis of many users' natural language utterances may lead to a steeper learning curve for speech recognition algorithms since adaptivity is based on a large and heterogeneous data set. While some SPAs rely on crowd data (Campagna et al., 2017), most do not (Schmeil & Broll, 2007).

**Representation** refers to presenting the user with a clearly identifiable service counterpart. In SPAs, this is mostly accomplished through anthropomorphism, “a conscious mechanism wherein people infer that a non-human entity has human-like characteristics and warrants human-like treatment” (Purinton et al., 2017, p. 2854). Anthropomorphic design is usually applied to provide a shared common ground, represent an authentic entity, combine verbal and nonverbal communication, and align minds by being interesting, creative, and humorous (McKeown, 2015; Schöbel, Janson, & Mishra, 2019). In practice, SPAs represent themselves either as virtual characters (or avatars) (Ochs et al., 2017), a (human-like) computer voice (Trovato et al., 2015b), or a combination of both (Zoric et al., 2005). However, some SPAs do not represent themselves at all (Armentano et al., 2006).

### 3.3.3 Taxonomy Evaluation

Meeting all ECs marks the end of the iterative taxonomy development process. However, Nickerson et al. (2013) also call for assessing the quality of the developed taxonomy according to five criteria: conciseness, robustness, comprehensibility, extendibility, and explanatory power. The taxonomy was evaluated with a series of ten interviews with carefully selected experts. We contacted researchers

and practitioners with expertise in either SPA research, SPA use in practice, or taxonomy development. Table B3 (Appendix B) provides an overview of the interviewees, their roles, and their expertise regarding the specific topic. The interviews lasted between 30 and 45 minutes and were conducted using semistructured interview guidelines between July and August 2019. The interview guidelines consisted of open questions addressing the five evaluation criteria. In order to prepare for the interview, the experts were provided with the taxonomy, the descriptions of the dimensions and characteristics, and the evaluation criteria in advance. Interviews were recorded, transcribed, and analyzed according to the five evaluation criteria. To illustrate the essence of the interviews, Table B4 (Appendix B) provides the core statements of the interview partners on each criterion. Results show that, to account for the current state of the art, the taxonomy (Table 1) does not require any modification. However, descriptions of the dimensions and characteristics lacked clarity at some points and were therefore adjusted accordingly.<sup>2</sup> Some statements also contained suggestions for future research. In the following, we present the summarized evaluation results.

*Conciseness* pertains to the number of dimensions that allow the taxonomy to be meaningful without being unwieldy or overwhelming. Our taxonomy contains eight dimensions with two to six characteristics each. In fact, all experts agreed that the dimensions and characteristics were well chosen and that the scope of the taxonomy neither cognitively overloads nor underchallenges the reader. In particular, the subdivision into hardware and intelligent agent characteristics was positively assessed. We have also provided descriptions and justificatory examples for each characteristic so that the taxonomy can be easily applied to characterize and classify SPAs.

*Robustness* means the dimensions and characteristics allow for differentiation among objects of interest and that statements can be made about sample objects with given characteristics. Since we defined the distinctiveness of each dimension-characteristic combination as an EC, each object in our set of 110 SPAs can be clearly distinguished. Also, the experts considered the characteristics and dimensions to be disjunctive and not overlapping. However, some experts wondered about the necessity of combining communication mode characteristics (e.g., voice and visual).

A *comprehensive* taxonomy allows for the classification of all objects within the domain of interest. Furthermore, all dimensions of the objects of

interest should be identified. Our sample for taxonomy development is based on our literature review and web search in the SPA identification phase, which revealed 86 SPAs in the scientific literature and an additional 24 SPAs developed for commercial purposes. Each SPA was iteratively classified in order to revise the taxonomy in five iterations. No dimensions or characteristics were added in the last iteration. Experts agreed that the taxonomy is both complete and comprehensive with regard to the state of the art. However, they stressed that comprehensive and complete explanations of the dimensions and characteristics are just as important as a comprehensive taxonomy.

*Extendibility* means that new dimensions or new characteristics of existing dimensions can be easily added. We have not made any restrictions or claims that the taxonomy is complete. In fact, we encourage future research to challenge and extend the taxonomy so that both more robust and more accurate taxonomies emerge, especially when new kinds of SPAs appear in research and practice. The experts agreed that the taxonomy is easily extendible because of the subdivision into intelligent agent and hardware characteristics. Future taxonomy extensions within the communication mode dimension, however, may quickly lead to combinatoric explosion because of the combined characteristics. In this case, one may consider violating the mutual exclusivity rule proposed by Nickerson et al. (2013) to ensure extendibility. However, in the current state of the taxonomy, the experts found that the combined characteristics do not affect the evaluation criteria.

Finally, dimensions and characteristics of an *explanatory* taxonomy explain yet unknown or opaque aspects of an object. Being mainly inductively developed, our taxonomy contributes to a clearer understanding of the material properties of SPAs in terms of smart services. The experts think that the taxonomy describes the material properties of SPAs well from a user interaction point of view. They consider it particularly useful for comparing material properties with requirements from practice.

### 3.4 SPA Grouping

Although the perception of affordances by users takes place at the level of material properties, these properties typically do not occur alone; they are bundled with several other material properties that also offer affordances and, as an ensemble, form the technical object. Assuming that structurally similar technical objects (i.e., SPAs with comparable material properties) afford similar action possibilities for value

<sup>2</sup> Note that the descriptions above are in a final (post-evaluation) state. Previous (pre-evaluation) descriptions have been adapted based on the highlighted statements in

Table B4 (Appendix B) and improved in terms of linguistic clarity.

co-creation, there may exist groups of SPAs that provide comparable affordances while being different from other such groups. The existence (or nonexistence) of such groups would allow us to concretize and delimit both the locus (the domain addressed) and the focus (the level of abstraction) in theorizing.

In order to find such groups, we employ a data-driven approach (Müller et al., 2016) by performing a cluster analysis on the SPAs according to the material properties summarized by the taxonomy (Table 1). The goal of a cluster analysis is to form groups of objects so that similar objects are in the same group and dissimilar objects are in different groups (Kaufman & Rousseeuw, 2009). While statistical tests are used for inferential or confirmatory purposes, such as proving or disproving hypotheses, we use cluster analysis as a descriptive, exploratory tool to identify patterns in data (Kaufman & Rousseeuw, 2009). Therefore, we dummy-coded each of the 110 SPAs identified in the literature and the web search so that each SPA is represented by a vector consisting of zeros and ones, where zero means that the SPA does not have the respective material property and one means that it does. Then, we calculated the distance (or dissimilarity) between each of the coded technical objects using the Dice similarity score (DSC; Dice, 1945). Compared to other distance measures that are suitable for categorical data (e.g., Goodall measures, inverse occurrence frequency measure, Lin measure), DSC assigns equal weights to all variables and does not assign higher (or lower) weights to (in)frequent (mis)matches. It is defined as:

$$DSC = \frac{2|X \cap Y|}{|X| + |Y|},$$

where  $|X|$  and  $|Y|$  are the cardinalities of two sets (i.e., objects). For the clustering of the data based on their

DSC, we performed a Partitioning Around Medoids (PAM) algorithm, a common realization of the  $k$ -medoid clustering procedure, in which objects are grouped into  $k$  clusters, each of which has one object of the data set as its center (medoid) (Kaufman & Rousseeuw, 2009). Like other partitioning clustering procedures (e.g.,  $k$ -means), the number of clusters  $k$  must be predetermined by the researcher. This can be complicated, since there is no single best statistical measure that ensures cohesion (high internal, or within-cluster, homogeneity), separation (high external, or between-cluster, heterogeneity), and meaningful interpretability of the cluster solutions. This makes it imperative for the researcher to combine statistical measures with practical judgment, common sense, and theoretical foundations (Balijepally et al., 2011). Thus, in order to receive an indication of a potentially good  $k$ , we calculated the silhouette score (Rousseeuw, 1987)—a measure of both cohesion and separation—for a two-cluster up to a ten-cluster solution. Results indicate that, based on our SPA data set, a five-cluster solution is statistically the most appropriate, as the objects match best with their own cluster and poorly with other clusters (indicated by a silhouette score of 0.446; Figure 5, for further details please see Appendix C).

Running PAM for a five-cluster solution in  $R$  reveals the frequency distribution of SPAs per Cluster C1 to C5 (columns) and per material property (row) shown in Table 2. Figure 6 further shows a dimensionality-reduced visualization of the cluster results.

As per the frequency of the material properties, the five clusters can be interpreted as different types of SPAs. We describe each cluster in detail below. For each cluster, the respective medoid (i.e., the cluster center) is taken as representative of the entire cluster population.

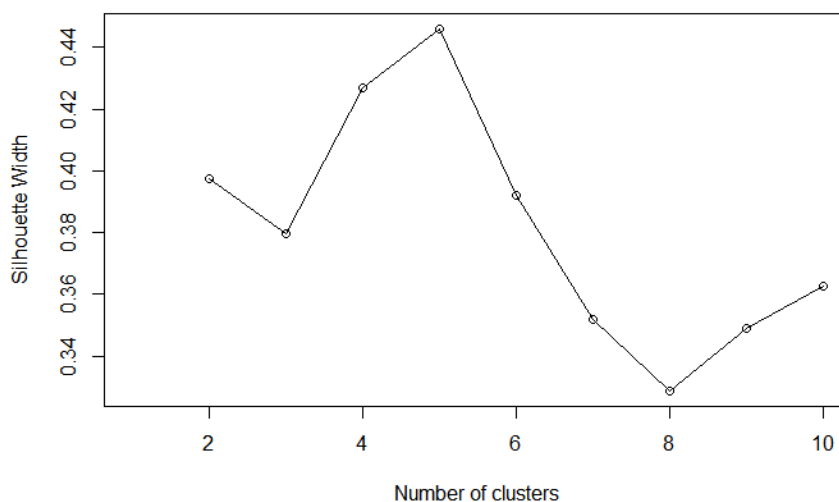
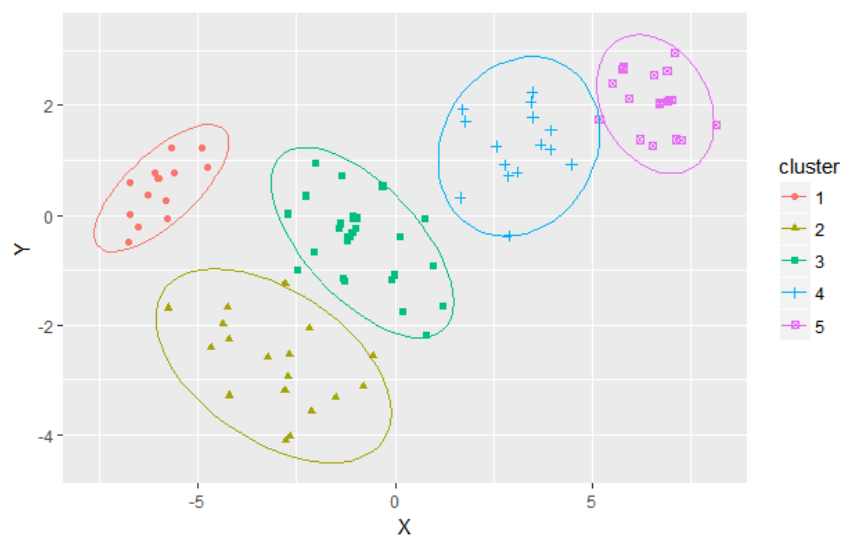


Figure 5. Silhouette Score for Different Cluster Solutions



**Table 2. Absolute Distribution of SPAs According to Material Property and Cluster**

	Amounts per MP	Amounts per cluster				
		C1	C2	C3	C4	C5
<b>Material properties (MPs)</b>	<b>110</b>	<b>18</b>	<b>21</b>	<b>33</b>	<b>15</b>	<b>23</b>
<b>Communication mode</b>						
- text	18	1	15	0	1	1
- voice	20	1	1	2	10	6
- visual	3	2	1	0	0	0
- text and visual	6	1	2	1	2	0
- voice and visual	55	5	2	30	2	16
- passive observation	8	8	0	0	0	0
<b>Directionality</b>						
- unidirectional	22	18	1	1	1	1
- bidirectional	88	0	20	32	14	22
<b>Integration</b>						
- no external control	64	14	18	31	1	0
- external control	46	4	3	2	14	23
<b>Knowledge model</b>						
- general	41	1	6	5	7	22
- specific	69	17	15	28	8	1
<b>Request complexity</b>						
- data	33	18	8	4	3	0
- primitive natural language	65	0	13	26	4	22
- compound natural language	12	0	0	3	8	1
<b>Adaptivity</b>						
- static behavior	64	17	15	21	11	0
- adaptive behavior	46	1	6	12	4	23
<b>Collective intelligence</b>						
- no crowd data	92	18	21	32	15	6
- crowd data	18	0	0	1	0	17
<b>Representation</b>						
- no representation	30	12	7	0	5	6
- virtual character	14	1	12	0	0	1
- artificial voice	23	1	1	1	7	13
- virtual character with voice	43	4	1	32	3	3



Note: Dimensionality of the data set was reduced by applying t-distributed stochastic neighbor embedding (t-SNE), a nonlinear dimensionality reduction technique to visualize high-dimensional objects by two- or three-dimensional points. For further information on t-SNE, see van der Maaten and Hinton (2008)

**Figure 6. Dimensionality-Reduced PAM Clustering Results**

### 3.4.1 Cluster 1: Data-Driven Active Observers

All SPAs in this cluster “observe” the behavior of the user by collecting context data and inform the user if a trigger event occurs (e.g., an increased heart rate during physical activity), communicating unidirectionally. The users are passive, they have few or no possibilities to enable value creation through self-initiated interaction. As data-driven active observers, Cluster 1 SPAs create a value-add during an already performed activity, for example by notifying users when the SPAs detect “anomalies” in context data or, in the best case, encouraging users to continue as before. Most data-driven active observers assist only with specific tasks, such as cooking or sightseeing. However, these knowledge models are rarely adaptive; they do not adapt to user behavior over time. These services also do not employ usage data from other users, e.g., for the statistical determination of alternative value creation opportunities or for service quality improvements. Since data-driven active observers are designed so that they do not disturb the conscious mind of the user, in most cases they have no visual or auditory representation in the form of avatars or computer-generated voices. The cluster medoid is WTAS, a Petri net-based wearable-task assistance system for industry applications that perceives the user’s physical environment and context changes to provide the user with appropriate context-oriented service (Xiahou & Xing, 2010).

### 3.4.2 Cluster 2: Chatbot Operators

SPAs of Cluster 2 mainly feature bidirectional text communication. Value creation in the service process only occurs when either the user or the technical object initiates the interaction via a text chat. Chatbot operators then react to user input based on the analysis of simple natural language text that, compared to technical objects using prespecified prompts or particular data structures, shifts the requirements for procedural and situational prior knowledge and for understanding the service counterpart away from the user and toward the technical object. Usually, chatbot operators also “reply” to user input in natural language via text synthesis. Apart from some exceptions, chatbot operators usually provide task-specific functionality such as first-level customer support on professional websites and are often not equipped with learning abilities. In smart services, these systems are often embodied as virtual characters (avatars) to enhance user experience. This cluster is represented by a digital coach for affective and social learning support (Schouten et al., 2018).

### 3.4.3 Cluster 3: Virtual Anthropomorphic Advisors

This is the largest cluster in terms of the number of assigned SPAs. It is characterized mainly by the

representation of the software agent as an anthropomorphic virtual character (avatar) with an artificial voice. These SPAs aim to enhance user experience via natural language, mimics, and gestures to provide familiar interaction and be empathic to the user. Often, they are designed to assist with a specific task or domain, such as e-learning. However, over half of the technical objects within our review can autonomously adjust to users’ preferences or usage behavior over the period of value creation. Therefore, they do not usually rely on collective intelligence or infer actions according to similar behavioral patterns of other crowd members. Virtual anthropomorphic advisors aim to transfer prior human-to-human activities such as tutoring to the virtual world while retaining the benefits of human-like traits such as empathy, humor, and responsiveness to ambiguous behavior. Anthropomorphism is suggested to be efficient for increasing acceptance of the technical object and, thus, positively influence outcomes of system use (e.g., a steeper learning curve; Purington et al., 2017). The medoid of this cluster is “Zara the Supergirl,” an empathic virtual (cartoon) character that recognizes speech, tone of voice, facial expressions, and content to analyze the user’s personality (Yang et al., 2017).

### 3.4.4 Cluster 4: Voice Facilitators

With a focus on human-like speech interaction, voice facilitators aim to make tasks previously performed by keyboard and screen interaction accessible to natural speech control. The set of technical objects includes (but is not limited to) SPAs for the elderly or visually impaired. Compared to technical objects in other clusters, these systems focus on performing the most natural speech interaction possible to provide a natural and familiar interaction experience. This requires the underlying linguistic model to not only respond to human utterances correctly but also to work with fillers such as “ah,” “um,” or speech pauses. Voice facilitators often understand compound commands and have outreach to the user’s digital world as well as control over smart objects, e.g., in the smart home. However, these SPAs typically neither rely on the usage data of the user crowd nor adapt to user behavior over time. Nethra, an intelligent assistant for the visually disabled to interact with internet services, is a representative example of this cluster (Weeratunga et al., 2015).

### 3.4.5 Cluster 5: General Activity Assistants

This cluster comprises SPAs that assist users during their daily activities by applying a general knowledge model. Typical application scenarios inform users about current events, play music, or make internet calls. Although most technical objects in this group combine voice and visual interaction—such as gesture control over integrated cameras or supplemental on-screen information—the systems are predominantly represented by a name and a computer-generated voice.

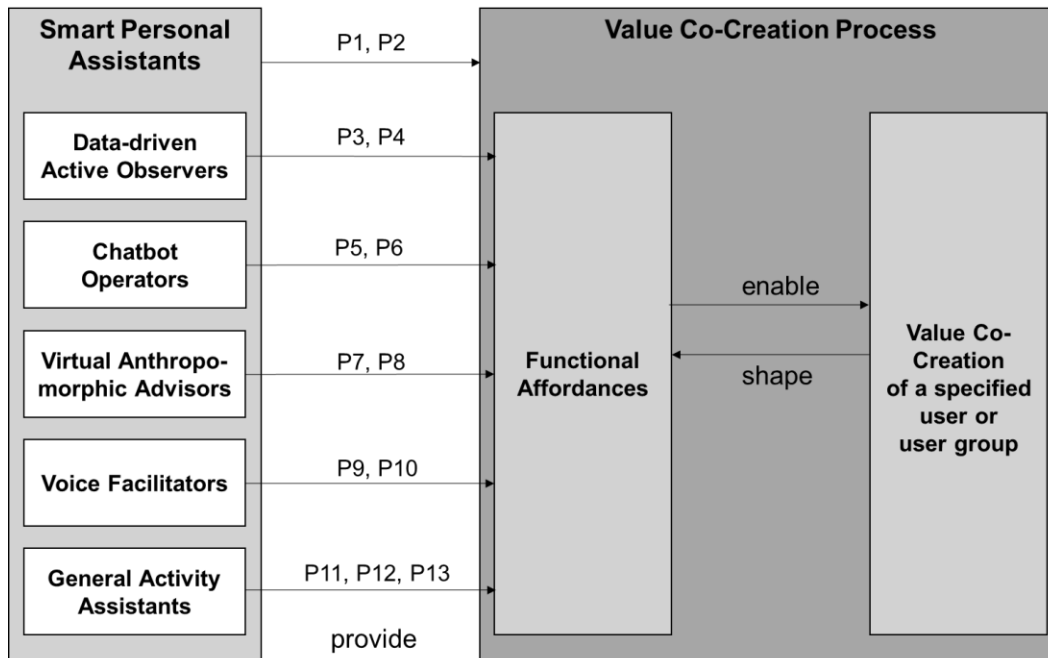


Figure 7. Logic of the Functional Affordances Perspective on Value Co-Creation in Smart Services

They typically understand primitive commands in natural language and execute (also third-party) services upon user request. This cluster includes all SPAs that have been developed for mass distribution on the consumer market (e.g., Alexa and Siri-powered devices). The developing firms can thus collect and evaluate usage data across systems, compare usage patterns, and adjust the systems to user behavior. Data collection and evaluation also enables the training of learning algorithms over time (e.g., to better understand users with dialects). An example of the cluster medoid is Amazon's Fire Tablet, powered by Alexa.

#### 4 Functional Affordances for Value Co-Creation in Smart Services

Considering the better understanding of value co-creation in smart services, and based on our analysis of SPAs in section three, we propose a theoretical model that captures the value co-creation process of SPAs through their specific affordances and affordance actualization processes (Figure 7). By this means, we distinguish between SPA affordances as some kind of potential for action and actualization defined as actions taken by individuals to realize the potentials of an SPA (Strong et al., 2014). Since the five cluster types of SPAs are structurally different, we posit that each affords different action possibilities to the user in the value co-creation process. Thus, we theorize on the identified clusters, showing how these SPAs and their inherent combinations of material properties provide various affordances in the value co-creation process.

We base our theoretical model on the earlier defined key constructs to make coherent claims about our phenomenon of interest (Grover et al., 2008; Weber, 2012). In consequence, the propositions of our theory form a deductive-nomological network of causal relationships (Bacharach, 1989) to better explain how value co-creation occurs in smart service systems. We discuss the theoretical propositions derived from the research model in detail below.

##### 4.1 Overarching Propositions

Before we delve into cluster-specific propositions, we derive two general propositions that influence all of the identified clusters. First, we note the overarching enabling effect of affordances on value co-creation as well as how value co-creation shapes the affordance perception and actualization in smart services. Therefore, we initially propose that major differences in value co-creation processes with SPAs result from the salient material properties of each cluster as well as from the unique affordances that may also be provided by the combination of these material properties. Connected to the latter is the consideration of the embeddedness of SPAs in smart services and the more complex co-creation processes related to the service system stakeholders that we also consider in our theory development. Thus, we posit the following overarching proposition:

**P1:** SPAs provide users different affordances according to their unique combinations of material properties that influence value co-creation in smart services.

Second, as highlighted in the theoretical model and the concept of functional affordances, we also note the overarching role of specific user groups, their needs, and specific value co-creation processes. Markus and Silver (2008) explain that affordance actualization is dependent on how the affordances are perceived, while the perceptions depend on the specific user group. For instance, digital natives (Vodanovich et al., 2010) may be accustomed to the communicative possibilities of an SPA (such as value co-creation possibilities through external integration in digital ecosystems) while other user groups such as the elderly may not be aware of these possibilities to co-create value. Hence, we state the second overarching proposition:

**P2:** SPAs provide different affordances for specified users or user groups, which in turn influences value co-creation in smart services.

Next, we discuss specific propositions by exploring how the properties of the different SPA clusters can affect the value co-creation process.

#### 4.2 Propositions Regarding Cluster 1: Data-Driven Active Observers

Being the only class of SPAs that primarily processes context data (instead of natural language, text, or visual stimuli), data-driven active observers work without the user consciously perceiving them. They mostly wait for a pattern to emerge from the collected contextual and usage data, which they can use as an opportunity to visually or audibly alert the user or directly execute a predefined action. After an initial period of familiarization, users will usually not notice the data collection and sensemaking of the system while they concentrate on their actual tasks. Data-driven active observers thereby provide added value to activities that users carry out. Therefore, we propose:

**P3:** Because of their unobtrusive nature, data-driven active observers afford users the ability to spend more cognitive load on the actual value-creating task rather than on interacting with the system.

However, most users will probably be aware that these SPAs can only work if they collect contextual and usage data over a longer period of time, even if users do not know when which data are collected. This may make users wary of disclosing information about their usage patterns (Hong & Thong, 2013), which in turn has a negative impact on usage of the SPA and, thus, on value co-creation. In addition, since data-driven active observers typically do not represent themselves as an avatar or a voice, users will probably trust these systems less compared to SPAs of other clusters (Lankton et al., 2015). Hence, we propose:

**P4:** If the user is aware that the data-driven active observer collects context and usage data, information disclosure barriers (such as privacy and trust concerns) will negatively influence value co-creation in smart services.

#### 4.3 Propositions Regarding Cluster 2: Chatbot Operators

With chatbot operators, value co-creation is characterized by bidirectional text-based interaction. The unique aspect of this cluster is its text-based communication that is more information-rich compared to voice-based communication. In other words, chatbot operators may provide more information in a single interaction to the user. Furthermore, the user can re-read parts of a text message. This can be particularly helpful if the message contains, e.g., multiple steps that should be conducted one after the other. In contrast, in voice-based communication, the cognitive processing of users may be more limited through the imposed cognitive load, and users might not comprehend more information-dense instructions effectively. Combined with a domain-specific knowledge model, which is dominant in this cluster of SPAs, we propose:

**P5:** Chatbot operators afford users the ability to effectively access and better understand large amounts of potentially consecutive information necessary for information-intensive value co-creation in a particular domain of interest.

Since most of the SPAs in this cluster also rely on representation through a virtual character, anthropomorphism may also influence the value co-creation process. Since chatbot operators only rely on virtual characters but do not try to mimic human voice, both the extreme positive and negative effects of personification and anthropomorphism (for more details, see Cluster 3) are unlikely to manifest for this cluster of SPAs. Prior research indicates that, especially in situations where users have high interest in value co-creation leading to beneficial outcomes (e.g., trading on electronic auction platforms), the degree to which users believe that they are interacting with a human or nonhuman counterpart affects emotional behavior so that lower levels of agency yield less overall arousal (Teubner et al., 2015). Instead, users and chatbot operators might establish a more distant but still noticeable relationship that— together with the domain knowledge of the chatbot operator—can be leveraged to position the chatbot operator as an expert in a certain area. Therefore, we propose:

**P6:** Chatbot operators afford users the ability to identify the technical object as an expert in a certain domain.



#### 4.4 Propositions Regarding Cluster 3: Virtual Anthropomorphic Advisors

A distinctive feature of virtual anthropomorphic advisors is that they attempt to simulate human behavior using a virtual avatar with voice. Prior studies indicate that high degrees of anthropomorphism may lead to greater personification (e.g., users referring to the assistant by its name instead of referencing it with object pronouns), which affords social and intense interaction with the technical object (Purinton et al., 2017). While users can react positively to greater personification, they can also react emotionally negatively to a highly anthropomorphized representation. This affection paradox is expressed by the uncanny valley phenomenon (Seymour et al., 2018), which suggests that users of human-like technical objects respond increasingly positively and empathetically until anthropomorphism reaches a point of conflict between appearance, behavior, and abilities, whereupon the system is perceived as strange or even repulsive. However, as anthropomorphism increases toward a point where a system becomes believably realistic, users' empathic responses generally increase and allow for value-creative human-computer interaction (Seymour et al., 2018). Hence, we propose:

**P7:** Depending on the degree of anthropomorphism of virtual anthropomorphic advisors, they afford users the ability to establish positive emotions (such as empathy) in order to increase users' satisfaction during and after value co-creation in a U-shaped manner.

Since the combination of bidirectional natural language, voice and visual interaction, and anthropomorphism may lead to personification of the technical object, users may include the SPAs in their inner social circle (Purinton et al., 2017). If this is the case, information privacy concerns may be overcome, affecting users' willingness to voluntarily disclose personal information (Smith et al., 2011). From an economic perspective, users cooperate in the gathering of data about themselves in order to obtain the benefits of the value co-creation process (Smith et al., 2011). Prior research shows that users perceive greater social presence—i.e., the degree to which a (technical) interaction counterpart is perceived as sociable, warm, sensitive, personal, or intimate (Lombard & Ditton, 1997)—when interacting with an STO with humanoid embodiment and human speech output (compared to the same STO with lower levels of anthropomorphism), which, in turn, increases trusting beliefs toward the more human-like STO (Qiu &

Benbasat, 2009). Since trusting beliefs have a negative relationship to information privacy concerns (Hong & Thong, 2013), we propose the following:

**P8:** Through their anthropomorphic design, virtual anthropomorphic advisors help users overcome information disclosure barriers in value co-creation.

On the other hand, service provision can also benefit from more user data, e.g., for personalized advertising or improvement of service quality. Hence, personification may be suitable for value co-creation in smart services in a reciprocal manner. However, the cluster analysis reveals that current forms of virtual anthropomorphic advisors do not autonomously adapt their behavior or affordances according to user data.

#### 4.5 Propositions Regarding Cluster 4: Voice Facilitators

When considering the rather small cluster of voice facilitators, value co-creation is typically derived through the unique combination of a voice-based-only communication mode paired with the more complex natural language component that makes affordances easy to actualize in specific domains. On this basis, our analysis highlights that this cluster of SPAs therefore either complements or fully replaces interaction modes in service co-creation processes, depending on specific user needs. While typical examples may include help to impaired people, as indicated in the cluster description, evolving user needs may also relate to the desire of users not to interact with other people in service consumption processes, e.g., as indicated through the development of driverless pizza delivery services as well as classic examples like customer self-services (Scherer et al., 2015). In addition, these affordances complement value co-creation in a greater ecosystem by offering the possibility to bundle up voice facilitator assistants through external control with other smart services, e.g., an advanced voice facilitator service (such as the Google Duplex<sup>3</sup> technology) that could be integrated with a general activity assistant. Thus, we posit the following two propositions.

**P9:** Voice facilitators afford users the ability to complement or replace interaction modes other than voice in value co-creation with respect to specific user needs.

**P10:** Voice facilitators afford users the ability to complement other smart services through external integration that enable/shape new value co-creation possibilities.

<sup>3</sup> For more information on Google Duplex, see <https://ai.googleblog.com/2018/05/duplex-ai-system-for-natural-conversation.html>.

## 4.6 Propositions Regarding Cluster 5: General Activity Assistants

The cluster of general activity assistants is unique in that it offers value co-creation for the general user. Through the general knowledge model of the technical object, a wide range of requests is possible from a wide range of users. For example, an Alexa-powered device is enabled to deal with algebraic operations as well as meal preparation advice. In tandem with the general knowledge model, the unique combination of external control facilitates the integration of general activity assistants in diverse ecosystems (e.g., Fire devices in the Alexa environment), which enables the exploration of more of the ecosystem to locate additional value. Therefore, we propose the following:

**P11:** General activity assistants afford users the ability to explore a wide range of value co-creation possibilities for different purposes within their ecosystem.

External control and integration in a complex service ecosystem enable the development of new services that make use of the SPA, thereby offering a broad range of affordances for users. Since the development of these service-system-integrated SPAs is ongoing, we highlight the dynamic nature of the enabled affordances. Such a dynamic integration of the SPA into the ecosystem enables collaborative affordances for both developers and companies to co-create value in smart services (Scacchi, 2010). This may include users that propose their own services—e.g., in its most simple form, by service recombination (Beverungen et al., 2018) through providers such as IFTTT<sup>4</sup>—or actualize affordances such as connectivity features based on ecosystem integration. Examples include the connectivity features of Amazon’s Alexa on the Echo and other devices. Furthermore, prior research indicates that, for general activity assistants, platform-related variables (i.e., network externalities) have a stronger effect on value co-creation than product-related variables (Park et al., 2018). Thus, we posit the following:

**P12:** General activity assistants afford smart service stakeholders the ability to co-create value through external integration, and, thus, shape affordances accordingly in a reciprocal and dynamic manner.

Finally, with the possibility to be adaptive and rely on crowd data, the general activity assistants cluster enables value co-creation through crowd-based processes. Through affordance actualization (e.g., when people use an Amazon Echo to provide assistance on To-Do lists), these SPAs enable users to co-create value for the overall

ecosystem in two ways. First, and most obviously, these assistants allow for correcting algorithmic decisions and training algorithms through customer co-creation. Second, and less obviously, through data analysis processes of affordance actualization, SPA providers can adjust their SPA and thus improve value co-creation. On this basis, we posit the following:

**P13:** General activity assistants rely on continuous adaptation in the affordance actualization processes through crowd data integration to improve value co-creation.

## 5 Discussion

Our paper makes three main contributions to the existing body of knowledge and provides a new theoretical perspective on the role of STOs in value co-creation in smart services. Focusing on SPAs in smart services, we first identified a set of material properties of SPAs that represent the current state-of-the-art knowledge concerning SPAs in both research and practice. For this purpose, we followed a rigorous taxonomy development process to capture material properties that are central for understanding how different clusters (or types) of SPAs provide unique functional affordances for value co-creation. Thereby, we contribute to service science and IS research by offering an STO-centric view on value co-creation in smart services.

Second, our findings contribute to understanding the exceptional value co-creation potential of SPAs by obtaining a functional affordances perspective. A contemporary functional affordance perspective that accounts for the dynamic nature of smart technology may explain value co-creation that results from STO use. We conceptualized an STO as a technical artifact that does not provide affordances in a static manner but rather collects context and usage data to dynamically reshape affordances and, consequently, has yet-to-be researched effects on value co-creation. Our research and propositions initiate a path for such research.

Third, as a practical contribution, our results help users and organizations to better understand the potential effects of SPAs. Based on this understanding, SPAs can be selected that fit the desired outcome of the firm or users. Furthermore, our results offer guidance to organizations seeking to develop a novel SPA by illuminating which material properties or type of SPA might be the best choice for their intended purpose. In the following, we discuss the implications of our contributions for both theory and practice.

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<sup>4</sup> IFTTT is the abbreviation of “If this then that.” As a web-based service to create chains of conditional statements, it connects for example SPA devices with other services based on action-based rules. For example, one could implement a

simple rule that “If an SPA timer (e.g., Alexa Echo) hits 0, smart home lights should blink and turn their color to red.”

## 5.1 Implications for Research on Value Co-Creation in Smart Services

Compared to the traditional understanding of value co-creation, either as direct exchange between humans or mediated by technology, value co-creation in smart services is likely to be fundamentally different because of the nature of smart technology and the functional affordances they provide to users.

For smart services in which SPAs act as service counterparts, we must assume that the formation of beliefs and attitudes such as service quality, trust, and information privacy concerns are different according to the functional affordances that an SPA provides. For example, empirical evidence from trust research shows that there are major differences in trust assessment according to social presence (i.e., anthropomorphic representation). This means that, with a technology perceived to have higher degrees of humanness, human-like trusting beliefs have a stronger influence on technology acceptance variables than system-like trusting beliefs and vice-versa (Lankton et al., 2015). We are firmly convinced that it is the responsibility of IS research to rethink and, consequently, reconceptualize the core components of the nomological net in view of the changing role of value co-creation. For example, service quality has evolved from being a core concept in human-to-human centered marketing and service research (Parasuraman et al., 1985) to being fundamentally reshaped by the advent of e-commerce. (Blut et al., 2015). Rethinking this concept and further investigating this evolution in the age of smart services is just one of the obvious next steps to understand value co-creation in smart services. Therefore, marketing, service science, and IS should form an interdisciplinary triad to conduct well-grounded theoretical, empirical, and—importantly—design research. Our propositions can help guide the exploration of value co-creation in smart services.

## 5.2 Implications for Research on Functional Affordances

Our findings also have implications for affordances theory. In general, our technology-centered approach toward functional affordances in smart services is complementary to needs-centered approaches that explore affordances from the perspective of specified user groups and their needs (e.g., Karahanna et al., 2018). However, the complementary nature of both perspectives on affordance theory may yield promising contributions and bridge gaps between social and technical research, and conclusively reinforce the importance of a sociotechnical perspective as an “axis of cohesion” for IS (Sarker et al., 2019). In other words, combining a sociotechnical perspective with either affordance-centric approach may help us understand effects and causalities in smart services

according to the changing nature and role of technology.

In this context, our paper also highlights the emergent and dynamic role of functional affordances. While functional affordances are often perceived as static, we provide a lens through which functional affordances can be seen as highly dynamic because of STOs’ material properties, such as the integration of crowd data, external control of other ecosystem entities, and anthropomorphic representation. Thus, material properties not only have the potential to provide affordances for users and user groups; in the long term, these material properties will help shape new affordances through value co-creation, reciprocally offering innovative ways to co-create values. We thus propose a contemporary view of the relationship between STOs, users, and functional affordances.

## 5.3 Contextualization and Operationalization of Propositions

This paper offers a first step toward distilling a comprehensive view of SPAs and their functional affordances to better understand value co-creation in smart services. While our technology-centered approach enabled us to derive more general insights concerning SPAs that are not idiosyncratic, this approach represents only an initial step toward understanding value co-creation in smart services. We task future research with obtaining a more contextualized view of SPAs (see Mallat et al., 2009, concerning the need for considering context in the understanding of services). Thus, in this section, we discuss particular aspects of contextualization in terms of our theory (Davison & Martinsons, 2016) and provide suggestions for the operationalization of our propositions in more specific value co-creation contexts.

As Markus and Silver (2008) highlight, affordances are dependent on their communicated values through symbolic expressions, and thus are perceived differently across users and user groups (see also Norman, 1999 concerning the perception of affordances). IS research suggests that the cultural background and values of users are related to the outcomes of technology use. For example, cultural conflicts may occur when new technology such as an SPA is introduced (Ernst et al., 2016; Leidner & Kayworth, 2006). Regarding the value of privacy (Dhillon et al., 2018; Hirschprung et al., 2016), one can argue that co-creation potentials are inhibited in, for example, (cultural) contexts in which privacy is valued more by individuals and user groups, compared to contexts in which privacy is more protected legally (Baruh et al., 2017; Smith et al., 2011). Examples might include pedagogical scenarios (Janson et al. 2020; Wambsganss et al. 2020), e.g., with students or

young high-school students that are supplemented with SPAs (Winkler et al. 2020; Winkler et al. 2021).

Thus, we suggest that there is a need to take the research model and propositions as a basis for further operationalization, especially when considering SPA clusters that relate to context-specific perceptions of users and user groups, e.g., data-driven observers and general activity assistants. For example, natural experiments in the field with users of SPAs such as general activity assistants could be conducted to test whether affordances are perceived differently across user groups (operationalizing P1) and to assess how value co-creation is influenced across these groups (operationalizing P2). Furthermore, design science research endeavors could use our propositions (such as P8, which proposes the effects of anthropomorphic design on information disclosure) as key components of design theories (Gregor & Jones, 2007), e.g., for the design of smart services. Thus, when contextualizing our theory in either behavioral or design-oriented research, our theory enables a deeper view of the effects of material properties on value co-creation processes.

## **5.4 Practical Implications**

The outcomes of this paper will also help practitioners better leverage the potential of SPAs in smart services for value co-creation. From an organizational perspective, smart services may be built around SPAs that, because of their material properties, offer different action possibilities. For example, while smart services that rely heavily on the provision of rich information may benefit from the deployment of chatbot operators, complex ecosystems may take more advantages from general activity assistants that integrate various resources and provide the affordance to explore other services within the ecosystem. For instance, an organization that has already built an ecosystem could deploy a general activity assistant (e.g., a smart speaker) to afford users the opportunity to explore new ways of value co-creation.

In particular, smart service providers that want to use SPAs for value co-creation with consumers could use our taxonomy to specify system requirements that match their particular use cases, contexts, and regulatory obligations. For example, the use of collective intelligence mechanisms for machine learning purposes may be critical in cases where sensitive personal information such as health records are processed. Furthermore, the results of the cluster analysis could help firms to acquire knowledge about common configurations of material properties that may inform both market research and their own SPA development processes. Finally, our proposed affordances indicate which value co-creation effects are likely to be expected when choosing or developing an SPA with a particular combination of material

properties. A reflection with dominant design characteristics of similar existing SPAs could help developers to choose between different design alternatives. From a user perspective, SPAs are likely to be adopted when functional affordances match individual values and contexts. Thus, our results may contribute to the better use of SPAs for specific value co-creation processes.

## **5.5 Limitations and Future Research**

Like all research, this study has limitations, which, however, offer avenues for future research. First, both taxonomy development and cluster analysis rely on an intentionally and deliberately limited data set. Future research should repeat object identification, structuring, and grouping with other and larger sets of STOs. The outcome of other such studies will add to our findings, further clarifying the nature of STOs and their role within smart services.

Second, although we tried to address salient feature combinations for each SPA cluster, the propositions that we developed cannot be assumed to be exclusively relevant to that particular cluster. Therefore, in addition to operationalizing and testing each individual proposition, future research should also test between-cluster differences for each proposition. For instance, one could test whether the personification of a general activity assistant and that of a virtual anthropomorphic advisor provide different affordances in the same value co-creation process, e.g., in the context of attempting to increase the learning outcome in a technology-mediated learning scenario.

Third, because of their degree of abstraction, our propositions appear to assume direct effects on value co-creation. In the course of contextualizing and operationalizing these propositions, there may have been potential moderating and mediating effects of other variables. Hence, developing such nomological nets would require future research to generate in-depth contextualized knowledge and to critically reflect prior theoretical work in the respective field. In addition, to find specific functional affordances of SPAs or other STOs, operationalization and contextualization require the specification of both the user group and the value to be co-created. In this context, we also note that we purposefully excluded symbolic expressions in the analysis of functional affordances, and therefore neglected the analysis of different user groups and how these user groups may draw on the potentials of such smart services. Thus, future research should also take into account the views of different user groups and how symbolic expressions influence the affordance actualization of SPAs.



## **6 Conclusion**

In this paper, we aimed to broaden the body of knowledge on value co-creation in smart services through the use of SPAs. Smart services offer entirely new possibilities for value co-creation (Ostrom et al., 2015). To better understand the role of different SPAs for value co-creation in smart services, we developed a taxonomy that supports the classification of SPAs according to their material properties. For developing our taxonomy, we relied on 110 different SPAs that we identified in scholarly literature and on commercial websites. Afterward, we conducted a PAM clustering analysis and identified five distinct clusters of SPAs: data-driven active observers, chatbot operators, virtual anthropomorphic advisors, voice facilitators, and general activity assistants. Looking through the lens of functional affordances theory, we developed two general and 11 cluster-specific propositions with regard to value co-creation in smart services.

Through our propositions, we established causal assumptions about how different combinations of material properties offer unique functional affordances for value co-creation. Our intention is to provide a basis for future empirical studies on value co-creation in smart services through STOs that pick up, operationalize, and evaluate our propositions in order

to deepen the body of knowledge in this important area for both IS research and practice.

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## Appendix A: Literature Review

The first step of our study was to identify SPAs in a literature view and an open web search for commercial SPAs. Below, we report details of the SPA identification phase.

**Table A1. Literature Review for Scholarly SPAs**

Steps	Databases and Numbers of Papers						Total
	ACM DL	AISel	EBSCO BSP	IEEE XPIore	ProQuest	Science Direct	
Search	800	26	136	1074	94	672	<b>2802</b>
Screening	123	20	27	110	11	63	<b>354</b>
Relevant	26	1	8	38	0	15	<b>91*</b>
Number of unique SPAs after consolidating multiple articles on the same SPA							<b>86</b>
*An additional Google Scholar backward and forward search revealed three more papers that were included in the data set. The total number in Table A1 includes these papers							

**Table A2. Web Review for Commercial SPAs**

SPA Name	Provider	Web reference to SPA
Aido	Aido	<a href="http://aidorobot.com">http://aidorobot.com</a>
BlackBerry Assistant	BlackBerry	<a href="https://help.blackberry.com/de/blackberry-classic/10.3.1/help/amc1403813572359.html">https://help.blackberry.com/de/blackberry-classic/10.3.1/help/amc1403813572359.html</a>
Bose Home Speaker 500 (Alexa)	Bose	<a href="https://www.bose.com/en_us/products/speakers/smart_home/bose-home-speaker-500.html">https://www.bose.com/en_us/products/speakers/smart_home/bose-home-speaker-500.html</a>
Braina Virtual Assistant	Brainasoft	<a href="https://www.brainasoft.com/braina/">https://www.brainasoft.com/braina/</a>
Dash Wand	Amazon	<a href="https://www.amazon.com/Amazon-Dash-Wand-With-Alexa/dp/B01MQMJFDK">https://www.amazon.com/Amazon-Dash-Wand-With-Alexa/dp/B01MQMJFDK</a>
Dragon Go!	Nuance	<a href="https://www.nuance.com/mobile/mobile-applications/dragon-mobile-assistant.html">https://www.nuance.com/mobile/mobile-applications/dragon-mobile-assistant.html</a>
Echo Plus, Echo Dot, Tap	Amazon	<a href="https://www.amazon.com/dp/B07H1QBW2L/">https://www.amazon.com/dp/B07H1QBW2L/</a>
Echo Look	Amazon	<a href="https://www.amazon.com/Amazon-Echo-Look-Camera-Style-Assistant/dp/B0186JAEWK">https://www.amazon.com/Amazon-Echo-Look-Camera-Style-Assistant/dp/B0186JAEWK</a>
Echo Show, Echo Spot	Amazon	<a href="https://www.amazon.com/dp/B077SXWSRP/">https://www.amazon.com/dp/B077SXWSRP/</a>
Fire Tablet	Amazon	<a href="https://www.amazon.com/b/?ie=UTF8&amp;node=6669703011">https://www.amazon.com/b/?ie=UTF8&amp;node=6669703011</a>
Google Home	Google	<a href="https://store.google.com/product/google_home">https://store.google.com/product/google_home</a>
Galaxy Home (Bixby)	Samsung	<a href="http://www.samsung.com/global/galaxy/apps/bixby/">http://www.samsung.com/global/galaxy/apps/bixby/</a>
harman kardon Invoke (Cortana)	harmand kardon & Microsoft	<a href="https://www.harmankardon.com/invoke.html">https://www.harmankardon.com/invoke.html</a>
Hey Athena	Hey Athena	<a href="https://rcbyron.github.io/hey-athena-website/docs/intro/overview.html">https://rcbyron.github.io/hey-athena-website/docs/intro/overview.html</a>
HomePod	Apple	<a href="https://www.apple.com/de/homepod/">https://www.apple.com/de/homepod/</a>
Hound	SoundHound Inc.	<a href="https://soundhound.com/hound">https://soundhound.com/hound</a>
Jibo	Jibo	<a href="https://www.jibo.com/">https://www.jibo.com/</a>
Lenovo TAB4 Home Assistant Speaker	Lenovo	<a href="https://www.lenovo.com/us/en/accessories/home-assistant/tab4-8-10-home-assistant/TAB4-Home-Assistant-Speaker-US/p/ZG38C02343">https://www.lenovo.com/us/en/accessories/home-assistant/tab4-8-10-home-assistant/TAB4-Home-Assistant-Speaker-US/p/ZG38C02343</a>
Lucida	Clarity Lab	<a href="http://lucida.ai/">http://lucida.ai/</a>
Mycroft	Mycroft AI	<a href="https://mycroft.ai/about-mycroft/">https://mycroft.ai/about-mycroft/</a>
Nina	Nuance	<a href="https://www.nuance.com/en-en/omni-channel-customer-engagement/digital/virtual-assistant/nina.html">https://www.nuance.com/en-en/omni-channel-customer-engagement/digital/virtual-assistant/nina.html</a>
SILVIA	Cognitive Code	<a href="https://www.silvia.ai/">https://www.silvia.ai/</a>
Sonos One	Sonos	<a href="https://www.harmankardon.com/invoke.html">https://www.harmankardon.com/invoke.html</a>
Viv	Viv Labs	<a href="http://viv.ai/">http://viv.ai/</a>

## Appendix B: Taxonomy Development

In this study, we analyzed SPAs to identify material properties that may lead to functional affordances for value co-creation with users. We therefore developed a taxonomy of material properties. Here, we provide details of the taxonomy development process.

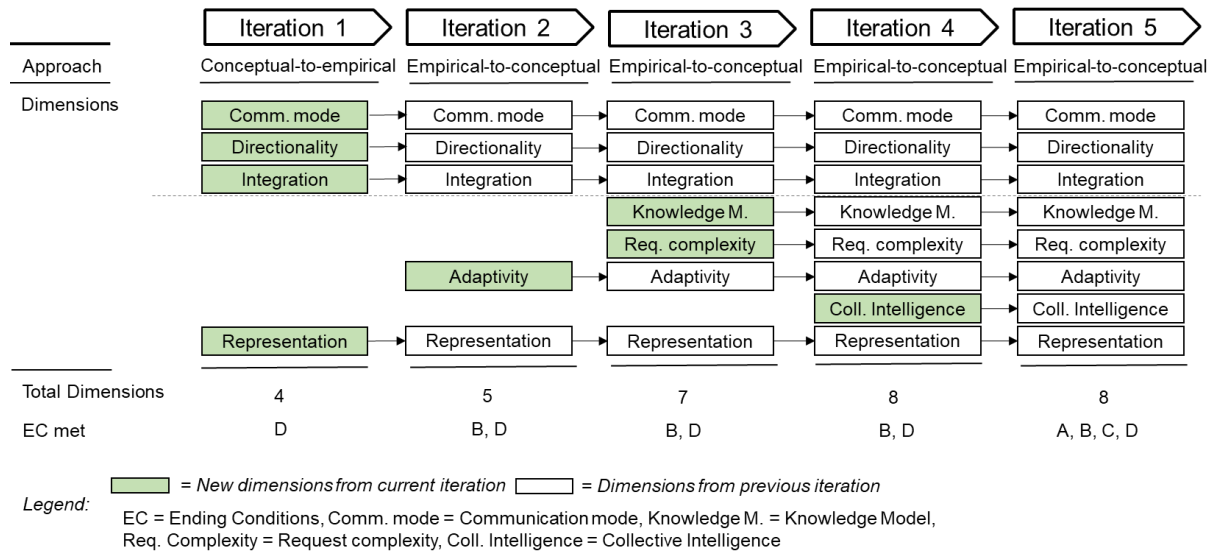


Figure B1. Taxonomy Development Iterations

Table B1. Derivation of Taxonomy Dimensions for First Conceptual-to-Empirical Iteration

Properties of smart products (Beverungen et al. 2017)	Implications for SPAs in smart services	First-iteration taxonomy dimensions and characteristics
<i>Unique Identification:</i> Clearly identifiable and distinguishable from other resources	In order to be identifiable in the interaction with end users, SPAs clearly represent themselves to users (Purington et al., 2017).	<i>Intelligent agent:</i> Representation (nonidentifiable, identifiable)
<i>Localizing:</i> Service can be configured and delivered based on the product's location	SPAs collect context data such as location to enable various value co-creation possibilities. They thereby offer passive (observational) and active (interactional) value co-creation possibilities (Jalaliniya & Pederson, 2015).	<i>Hardware:</i> Communication mode (active interaction, passive observation)
<i>Invisible computers:</i> Service delivery with little (if any) user attention. Data collection is possible without users' knowledge		
<i>Sensors:</i> Based on contextual data and usage data, service can be tailored to the context of the product		
<i>Connectivity:</i> Integration with remote resources to co-create service by integrating skills, knowledge, and resources	SPAs integrate various knowledge, skills, resources, activities, and information systems to have external outreach (Jalaliniya & Pederson, 2015).	<i>Hardware:</i> Integration (no external control, external control)
<i>Storage and Computation:</i> Local service offering with data available for analysis in near real time		
<i>Actuators:</i> Manifestation in and effect on physical environment		
<i>Interfaces:</i> Service is co-created in local interactions between smart products and users	Co-creation with SPAs usually requires bidirectional interaction. However, when data are collected without users' knowledge, this is unidirectional interaction (Jalaliniya & Pederson, 2015).	<i>Hardware:</i> Directionality (unidirectional, bidirectional)

**Table B2. Evolution of Taxonomy Dimensions and Characteristics per Iteration**

It. #	Approach	Taxonomy	EC met
1	Conceptual-to-empirical	T <sub>1</sub> = {Communication mode (active interaction, passive observation), Directionality (unidirectional, bidirectional), Integration (no external control, external control) Representation (non-identifiable, identifiable)}	D
2	Empirical-to-conceptual	T <sub>2</sub> = {Communication mode (text, voice, visual, text and visual, passive observation), Directionality (unidirectional, bidirectional), Integration (no external control, external control), Adaptivity (static behavior, adaptive behavior), Representation (none, virtual character, artificial voice)}	B, D
3	Empirical-to-conceptual	T <sub>3</sub> = {Communication mode (text, voice, visual, text and visual, voice and visual, passive observation), Directionality (unidirectional, bidirectional), Integration (no external control, external control), Knowledge model (specific, general), Request complexity (data, natural language), Adaptivity (static behavior, adaptive behavior), Representation (none, virtual character, artificial voice, virtual character with voice)}	B, D
4	Empirical-to-conceptual	T <sub>4/5</sub> = {Communication mode (text, voice, visual, text and visual, voice and visual, passive observation), Directionality (unidirectional, bidirectional), Integration (no external control, external control), Knowledge model (specific, general), Request complexity (data, primitive natural language, compound natural language), Adaptivity (static behavior, adaptive behavior), Collective Intelligence (no crowd data, crowd data), Representation (none, virtual character, artificial voice, virtual character with voice)}	B, D
5	Empirical-to-conceptual		A, B, C, D

*Note:* It. # = Iteration Number; EC = Ending Condition(s)

**Table B3. Overview of Interview Partners for Taxonomy Evaluation**

No.	Function	Organization	Expertise in
1	Researcher	University	<i>Taxonomy development</i> – Developed taxonomy and classifications for digital work
2	Researcher	International business school	<i>Taxonomy development</i> – Developed taxonomy and various classifications for analytics-based services
3	Researcher	University	<i>Taxonomy development</i> – Developed taxonomy and various classifications for gamified information systems
4	Researcher	International business school	<i>Taxonomy development</i> – Developed taxonomy and classifications for trust in information systems
5	Researcher	International business school	<i>SPA research</i> – Conducted experimental and design-oriented research with SPAs in the learning context
6	Researcher	University	<i>SPA research</i> – Developed smart learning systems with SPAs
7	Researcher	International business school	<i>SPA research</i> – Developed and evaluated learning management systems and SPAs, especially chatbots
8	IT strategy consultant	Financial institute	<i>SPAs in practice</i> – Conducts market research and requirements analysis for both internal and external use of SPAs



9	E-learning project manager	Medical company	<i>SPAs in practice</i> – Conducts requirement analyses and proofs-of-concepts for SPAs in corporate e-learning
10	Data scientist	Insurance company	<i>SPAs in practice</i> – Implements SPAs and transforms insurance services towards voice control

Table B4. Core Statements from Evaluation Interviews

Evaluation Criteria (Nickerson et al., 2013)	Core Statements	Mentioned by Interviewee No. <sup>1</sup>
Concise	<p>Taxonomy and descriptions are formulated well.</p> <p>Differentiation between Hardware and Intelligent Agent dimensions is reasonable.</p> <p>Total number of dimensions is appropriate.</p> <p>The total number of dimensions does neither cognitively overload nor underchallenge the reader.</p> <p>All dimensions are at the same level of abstraction.</p>	<p>1, 4, 8, 9</p> <p>1, 3</p> <p>2 - 5, 8, 10</p> <p>6, 7, 9</p> <p>7</p>
Robust	<p>Taxonomy is applicable to describe and differentiate SPA's by their material properties.</p> <p>Dimensions and Characteristics are disjunct and not overlapping.</p> <p>Mutual exclusivity requirement leads to combined characteristics that may lead to confusion (c.f. results for Extendible).<sup>3</sup></p>	<p>1, 2, 6, 10</p> <p>4, 6 - 9</p> <p>3, 5, 6, 8</p>
Comprehensive	<p>Taxonomy allows for a complete and comprehensive description of objects.</p> <p>Dimensions are complete regarding goal, metacharacteristic and state of the art.</p> <p>Dimension descriptions are equally important for a comprehensive taxonomy.</p> <p>Suggestions: Integration should include connection with both other systems and users' digital profiles<sup>2</sup> Description of communication mode should emphasize that it is about the predominant communication mode<sup>2</sup></p>	<p>2, 4, 5, 8, 9</p> <p>1 - 6; 8, 9</p> <p>3, 10</p> <p>1, 10</p> <p>2</p>
Extendible	<p>Dimensions can easily be added to the taxonomy.</p> <p>Characteristics can easily be modified or added.</p> <p>Mutual exclusivity requirement may lead to increasing combinatorial complexity when the taxonomy is extended.<sup>3</sup></p>	<p>1, 2, 4 - 7, 9, 10</p> <p>1, 6, 7, 10</p> <p>3, 4, 6</p>
Explanatory	<p>Taxonomy (including dimension descriptions) explains the material properties of SPAs well.</p> <p>Taxonomy is useful for comparing material properties with system requirements in practice.</p>	<p>1-10</p> <p>8, 9</p>
<p>Note: <sup>1</sup> = cf. Table B3; <sup>2</sup> = statement led to an adaption of dimension descriptions; <sup>3</sup> = statement to be considered by future research</p>		

**Table B5. Concept Matrix including Sources, Classification of Characteristics and Final Cluster for all SPAs**

SPA (Source)	Taxonomy characteristics								Final Cluster
	Hardware			Intelligent agent					
	Communication mode	Directionality	Integration	Knowledge model	Request complexity	Adaptivity	Collective intelligence	Representation	
Adam, Cavedon, & Padgham (2010)	voice	bidir	no ec	specific	cnl	adaptive	no cd	av	4
ADVICE Project (García-Serrano, Martínez, & Hernández, 2004)	t&v	bidir	ec	specific	cnl	adaptive	no cd	vc&v	4
Aido*	v&v	bidir	ec	general	pnl	adaptive	no cd	vc	5
AINI (Goh, Fung, Wong, & Depickere, 2006)	text	bidir	no ec	specific	pnl	static	no cd	vc&v	2
Almond (Campagna et al., 2017)	text	unidir	ec	general	cnl	adaptive	cd	none	5
Amazon Dash Wand, powered by Alexa*	voice	bidir	ec	general	pnl	adaptive	cd	av	5
Amazon Echo Look, powered by Alexa*	v&v	bidir	ec	specific	pnl	adaptive	cd	none	5
Amazon Echo Plus, Echo Dot & Tap, powered by Alexa*	voice	bidir	ec	general	pnl	adaptive	cd	av	5
Amazon Echo Show & Echo Spot, powered by Alexa*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Amazon Fire Tablet, powered by Alexa*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Ana / Kobian (Trovato et al., 2015b, 2015a)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Apple HomePod*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Armentano et al. (2006)	text	bidir	no ec	general	data	adaptive	no cd	none	2
AutoTutor (Graesser et al., 2005)	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
Ayedoun, Hayashi, & Seta (2015)	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
BASEBALL (Green Jr. et al., 1961)	text	bidir	no ec	specific	pnl	static	no cd	none	2
Bickmore, Schulman, & Sidner (2013)	t&v	bidir	no ec	general	pnl	adaptive	no cd	vc&v	3
Blackberry Assistant*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
BOSE Home Speaker 500, powered by Alexa*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Braina Virtual Assistant*	v&v	bidir	ec	general	pnl	adaptive	no cd	av	5
CALMsystem (Kerly, Ellis, & Bull, 2008)	text	bidir	no ec	specific	data	adaptive	no cd	none	2
Chen et al. (2014)	po	unidir	ec	specific	data	static	no cd	none	1
Clarity Lab Lucida*	v&v	bidir	no ec	general	pnl	static	no cd	av	3
COGAS (Özyurt, Döring, & Flemisch, 2013)	t&v	unidir	no ec	specific	data	static	no cd	none	1
Cognitive Code SILVIA*	v&v	bidir	ec	general	pnl	adaptive	cd	vc&v	5
DI@L-log (Griol et al., 2013)	voice	bidir	ec	specific	data	static	no cd	av	4

DIVA (De Carolis, De Gemmis, & Lops, 2015)	po	unidir	no ec	specific	data	static	no cd	vc	1
Den Os, Boves, Rossignol, ten Bosch, & Vuurpijl (2005)	v&v	bidir	no ec	specific	data	static	no cd	vc&v	3
DIVAlite (Sansonnnet et al., 2012)	text	unidir	ec	general	data	static	no cd	vc	2
Doumanis & Smith (2014)	v&v	unidir	no ec	specific	data	static	no cd	vc&v	1
Duer (Haifeng Wang, 2016)	v&v	bidir	ec	general	pnl	adaptive	no cd	none	5
DynamicDuo (Trinh, Ring, & Bickmore, 2015)	v&v	bidir	no ec	specific	data	static	no cd	vc&v	3
Eisman, Navarro, & Castro (2016)	text	bidir	ec	general	cnl	static	no cd	vc&v	4
ELIZA (Weizenbaum, 1966)	text	bidir	no ec	general	pnl	static	no cd	none	2
EMMA (Boukricha & Wachsmuth, 2011)	v&v	bidir	no ec	general	pnl	static	no cd	vc&v	3
ESCAP (Rudra, Li, & Kavakli, 2012)	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
E-VOX (Pérez, Cerezo, & Serón, 2016)	t&v	bidir	no ec	specific	pnl	adaptive	no cd	vc	2
Fairy Agent (Yoshii & Nakajima, 2015)	text	bidir	no ec	specific	data	static	no cd	vc	2
Fudholi, Maneerat, & Varakulsiripunth (2009)	text	unidir	no ec	specific	data	static	no cd	none	1
Gnjatovic, Suzic, Morosev, & Delic (2012)	voice	unidir	ec	specific	pnl	static	no cd	av	4
Google Home, powered by Google Assistant*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Harman kardon Invoke, powered by Microsoft Cortana*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Hasegawa, Ugurlu, & Sakuta (2014)	v&v	unidir	no ec	specific	data	static	no cd	vc&v	1
Hayashi (2013)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Hey Athena*	voice	bidir	ec	general	pnl	static	no cd	av	4
Huang, Baba, & Nakano (2011)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Hubal et al. (2008)	v&v	bidir	no ec	specific	cnl	static	no cd	vc&v	3
Humorist Bot (Augello, Saccone, Gaglio, & Pilato, 2008)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
HWYD Companion (Cavazza, de la Camara, & Turunen, 2010)	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
I feel Lucky (Onorati, Malizia, Olsen, Diaz, & Aedo, 2012)	po	unidir	ec	general	data	static	no cd	none	1
Imtiaz et al. (2014)	visual	unidir	no ec	specific	data	static	no cd	none	1
IPA Agent (Czibula, Guran, Czibula, & Cojocar, 2009)	po	unidir	no ec	specific	data	adaptive	no cd	none	1
Ishii, Nakano, & Nishida (2013)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Iwamura, Kunze, Kato, Utsumi, & Kise (2014)	po	unidir	no ec	specific	data	static	no cd	none	1

Jalaliniya & Pederson (2015)	visual	unidir	no ec	specific	data	static	no cd	none	1
Jibo*	voice	bidir	ec	general	pnl	adaptive	no cd	vc&v	5
KASPAR (Wainer, Robins, Amirabdollahian, & Dautenhahn, 2014)	v&v	unidir	no ec	specific	data	static	no cd	vc&v	1
Lakde & Prasad (2015)	voice	unidir	no ec	specific	data	static	no cd	av	1
Lenovo TAB4 Home Assistant Speaker*	voice	bidir	ec	general	pnl	adaptive	cd	av	5
López, Eisman, & Castro (2008)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Louise (Wargnier et al., 2016)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
LUNAR (Woods & Kaplan, 1977)	voice	bidir	ec	specific	pnl	static	no cd	vc	2
MACH (Hoque, Courgeon, Martin, Mutlu, & Picard, 2013)	v&v	unidir	no ec	specific	data	static	no cd	vc&v	1
MARA (Schmeil & Broll, 2007)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
MAS Punda (Dybala, Ptaszynski, Rzepka, & Araki, 2010)	text	bidir	no ec	general	pnl	static	no cd	none	2
Max (Krämer, Kopp, Becker-Asano, & Sommer, 2013)	v&v	bidir	no ec	general	cnl	adaptive	no cd	vc&v	3
MentorChat (Tegos & Demetriadis, 2017; Tegos, Demetriadis, & Karakostas, 2011, 2014a, 2014b, 2015; Tegos, Demetriadis, & Tsiatsos, 2012)	text	bidir	no ec	specific	pnl	adaptive	no cd	vc	2
Mihale-Wilson et al. (2017)	v&v	bidir	ec	general	pnl	adaptive	no cd	vc&v	5
MimiCook (Sato, Watanabe, & Rekimoto, 2014)	po	unidir	ec	specific	data	static	no cd	none	1
Miyake & Ito (2012)	v&v	bidir	ec	specific	pnl	static	no cd	vc&v	3
MobiSpeech (Abdelkefi & Kallel, 2016)	v&v	unidir	no ec	specific	data	static	no cd	none	1
Moussa et al. (2010)	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
Mycroft AI Mycroft*	voice	bidir	ec	general	pnl	static	no cd	vc&v	4
Nam, Nagwani, Jang, Shin, & Jin (2016)	po	unidir	ec	specific	data	static	no cd	none	1
Nao (Kanaoka & Mutlu, 2015)	voice	bidir	no ec	specific	pnl	static	no cd	vc&v	3
Neel (Datta & Vijay, 2010)	v&v	bidir	no ec	specific	data	adaptive	cd	vc&v	3
Nethra (Weeratunga et al., 2015)	voice	bidir	ec	specific	cnl	static	no cd	av	4
Nicky (Kincaid & Pollock, 2017)	text	bidir	no ec	specific	pnl	static	no cd	av	2
Niewiadomski & Pelachaud (2010)	visual	bidir	no ec	general	data	static	no cd	vc	2
Nuance Dragon Go!*	voice	bidir	ec	general	pnl	adaptive	cd	none	5
Nuance Nina*	v&v	bidir	ec	general	pnl	adaptive	cd	av	5
Nunamaker et al. (2011)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
ODVIC (Lisetti, Amini, Yasavur, & Rische, 2013)	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3

<i>Oscar (Latham, Crockett, McLean, Edmonds, &amp; O'Shea, 2010)</i>	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc	2
<i>PaeLife Personal Life Assistant (Teixeira et al., 2014)</i>	voice	bidir	ec	specific	pnl	static	no cd	none	4
<i>Paraiso &amp; Barthes (2005)</i>	voice	bidir	ec	general	cnl	static	no cd	none	4
<i>Pat (Derrick &amp; Ligon, 2014)</i>	text	bidir	ec	specific	data	static	no cd	vc	2
<i>PDA (Sugawara et al., 2011)</i>	text	bidir	no ec	specific	pnl	static	no cd	none	2
<i>Rea (Cassell, 2000)</i>	v&v	bidir	no ec	general	data	static	no cd	vc&v	3
<i>Robin (van der Zwaan &amp; Dignum, 2013)</i>	t&v	bidir	no ec	specific	data	static	no cd	vc	2
<i>SAETA (Vales-Alonso et al., 2015)</i>	v&v	bidir	ec	specific	data	adaptive	no cd	none	4
<i>Samsung Galaxy Home, powered by Bixby*</i>	v&v	bidir	ec	general	pnl	adaptive	no cd	none	5
<i>Santos et al. (2016)</i>	t&v	bidir	ec	specific	data	static	no cd	none	4
<i>Santos-Perez, Gonzalez-Parada, &amp; Cano-garcia (2013)</i>	v&v	bidir	ec	specific	pnl	adaptive	no cd	vc&v	3
<i>SARA (Niculescu et al., 2014)</i>	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
<i>Schouten et al. (2018)</i>	text	bidir	no ec	specific	pnl	static	no cd	vc	2
<i>Sirius (Hauswald et al., 2016)</i>	v&v	bidir	ec	general	cnl	static	no cd	none	4
<i>Shabette Concier (Tsujino et al., 2013)</i>	voice	bidir	ec	general	cnl	adaptive	no cd	av	4
<i>Shamael (Pérez-Marín &amp; Pascual-Nieto, 2013)</i>	text	bidir	no ec	specific	data	static	no cd	vc	2
<i>Song, Oh, &amp; Rice (2017)</i>	text	bidir	no ec	specific	pnl	adaptive	no cd	none	2
<i>Sonos One*</i>	voice	bidir	ec	general	pnl	adaptive	cd	av	5
<i>SoundHound Inc. Hound*</i>	voice	bidir	ec	general	cnl	static	no cd	av	4
<i>Victor (Grujic et al., 2009)</i>	v&v	unidir	no ec	specific	pnl	static	no cd	vc&v	3
<i>Viv Labs Viv*</i>	v&v	bidir	ec	general	pnl	adaptive	cd	none	5
<i>WTAS Framework (Xiahou &amp; Xing, 2010)</i>	po	unidir	no ec	specific	data	static	no cd	none	1
<i>xGECA (Hacker et al., 2009)</i>	v&v	bidir	no ec	general	pnl	static	no cd	vc	2
<i>Young Merlin (Gris, Rivera, Rayon, Camacho, &amp; Novick, 2016)</i>	v&v	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3
<i>Zara the Supergirl (Yang et al., 2017)</i>	v&v	bidir	no ec	specific	pnl	static	no cd	vc&v	3
<i>Zhang, Bickmore, &amp; Paasche-Orlow (2017)</i>	v&v	bidir	no ec	specific	cnl	static	no cd	vc&v	3
<i>Zia-ul-Haque, Wang, Li, Wang, &amp; Yujun (2007)</i>	voice	bidir	no ec	specific	pnl	adaptive	no cd	vc&v	3

*Note:* = \*see table A2 for commercial SPA references. t&v = text and visual; v&v = voice and visual; po = passive observation; unidir = unidirectional; bidir = bidirectional; no ec = no external control; ec = external control; pnl = primitive natural language; cnl = compound natural language; no cd = no crowd data; cd = crowd data; vc = virtual character; av = artificial voice; vc&v = virtual character with voice; none = no representation



## Appendix C: Cluster Analysis

We clustered SPAs according to their material properties, so that systems match best with their own cluster and poorly with other clusters. We conducted cluster analysis with attention to three essential objectives: cohesion (high internal, or within-cluster, homogeneity), separation (high external, or between-cluster, heterogeneity), and meaningful interpretability of the cluster solutions. In the following, we report the silhouette score of different cluster solutions for our PAM clustering approach. We further provide a link to an online repository where the cluster algorithm (R file) is available for transparency and reproducibility purposes:

[http://downloads.wi-kassel.de/Appendices/clustering\\_JAIS-public.R](http://downloads.wi-kassel.de/Appendices/clustering_JAIS-public.R)

**Table C1. Silhouette score of different cluster solutions (also see Figure 5)**

<b>n Clusters</b>	2	3	4	5	6	7	8	9	10
<b>Silhouette Score</b>	.397	.380	.427	.446	.392	.352	.329	.349	.363

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