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How Big Data Analytics Enables Service Innovation: Materiality, Affordance, and the Individualization of Service

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Abstract: The article reports on an exploratory, multisite case study of four organizations from the insurance, banking, telecommunications, and e-commerce industries that implemented big data analytics (BDA) technologies to provide individualized service to their customers. Grounded in our analysis of these four cases, a theoretical model is developed that explains how the flexible and reprogrammable nature of BDA technologies provides features of sourcing, storage, event recognition and prediction, behavior recognition and prediction, rule-based actions, and visualization that afford (1) service automation and (2) BDA-enabled human-material service practices. The model highlights how material agency (in the case of service automation) and the interplay of human and material agencies (in the case of human-material service practices) enable service individualization, as organizations draw on a service-dominant logic. The article contributes to the literature on digitally enabled service innovation by highlighting how BDA technologies are generative digital technologies that provide a key organizational resource for service innovation. We discuss implications for research and practice.

Key words and phrases: affordances, agency, big data analytics, digital innovation, materiality, service-dominant logic, service innovation, services.

The increasing commoditization of products and the rising customer demand for individualized experiences and interactions is causing chief executives to shift their focus from product innovation to service innovation [1]. Service innovation offers customers new and unique value propositions that allow companies to differentiate themselves from their competitors and to create strategic value [45]. Companies are thus seeking opportunities to capitalize on the flexible and malleable nature of digital technologies to innovate their service (e.g., [1, 24, 57]),[1] and service innovation is now an important area in the broader field of digital innovation [57].

The ever increasing abundance of digital trace data, coupled with advances in big data analytics (BDA), in particular, offer new possibilities for service innovation [1, 58]. BDA provides powerful methods and tools for gathering, processing, and analyzing large

amounts of trace data, enabling organizations to generate valuable insights by compiling their customers' "digital footprints into a comprehensive picture of an individual's daily life" [60, p. 21]. These insights have the potential to create competitive advantage [6, 14, 32], and BDA is expected to support customer-oriented service innovation in a number of ways [34, 58].

Analyzing data gathered from sensors in cars, for instance, allows insurance firms to create offerings that are sensitive to their customers' driving behavior [32]. Whirlpool, the home-appliances manufacturer, uses sensors in their products to track how customers use their products, combine these data with user-generated content from social media platforms, and generate insights into their customers' preferences and behaviors [54]. While these examples suggest that BDA provides ample opportunity for service innovation across industries, we lack an empirically grounded theoretical understanding that attends to the materiality of BDA and how this materiality enables service innovation. Such a theoretical account will have to consider the role of both human and material agencies, as service, which has traditionally been a human enterprise, is now increasingly shaped by the use of digital technologies. Material agency describes a technology's capacity to act on its own, apart from human intervention, while human agency refers to humans' capacity to form and realize their goals [21]. Developing such an empirically grounded theoretical model will complement and contribute to previous scholarly work on digitally enabled service innovation, which has highlighted how the generative nature of digital technologies enables service innovation [24, 58]. In addition, organizations that seek to innovate their service can benefit from such a model in their efforts to identify and implement appropriate BDA technologies. Moreover, developing theory on the impact of BDA on service innovation can contribute to the development of more general theories of digitally enabled service innovation. Therefore, our research question is:[2]

How do the material features of big data analytics technologies enable service innovation?

Our study has three primary objectives: (1) to develop an empirical description of how BDA has been used to develop service innovation, (2) to identify the pertinent material features of BDA that facilitate the implementation of service innovation, and (3) to integrate these findings into an empirically grounded theoretical model of BDA-enabled service innovation. To this end, we conducted four exploratory, theory-building case studies [9, 35] with private-sector business-to-customer (B2C) firms, which allowed us to gain an in-depth understanding of how BDA permitted these organizations to identify opportunities for new BDA-enabled service processes and their implementation. To develop an understanding of the more specific role of BDA, we draw on recent research on the role of materiality in IT-enabled change and innovation (e.g., [21, 22, 47]), as we are interested in what matters about BDA technologies in developing service innovation. Specifically, we use the concepts of materiality and affordances as analytical devices because they are predominant

lenses through which to theorize about how digital technologies are involved in organizational change and innovation (e.g., [11, 12, 19, 21, 25, 26, 42]).

Our analysis suggests two main types of BDA-enabled service innovation. First, organizations use key material features of BDA technologies to automate service processes in order to provide (a) trigger-based service actions and (b) preference-based service actions to customers. Second, organizations identify new ways for IT-enabled service processes where human service actors interact with BDA technologies (i.e., human-material service practices) to engage in trigger-based interactions and preference-based interactions with customers. In both cases, service innovation is based on the generativity and reprogrammability of BDA technologies as digital technologies [58].

The present research makes three primary contributions to theory and practice. First, it contributes to the literature on service innovation by providing an empirically grounded theoretical model of how the material features of BDA technologies enable service innovation, as organizations interpret BDA technologies as general-purpose technologies in light of new action goals associated with a service-dominant logic [24]. Second, we contribute to the literature on digital innovation [30, 57, 58] in more general terms by highlighting how digital technologies afford two fundamentally different types of digital innovation: automation, which relies on material agency, and human-material practices, which relies on the interaction between human and material agencies. Third, our research yields practical insights for the design of BDA infrastructures that support service innovation. The proposed conceptualization provides the guidance for assessing current infrastructures and for making decisions about the implementation of new technologies.

Theoretical Background

Service innovation

Service innovation provides businesses with opportunities to create customer value and generate competitive advantage. The view of service innovation has shifted from a focus on firms' output (i.e., in terms of new or improved products and services) to a focus on new ways of creating customer value through service processes, so the shift has been from a goods-dominant (G-D) logic to a service-dominant (S-D) logic. From the G-D perspective, service innovation is the production of outputs in the form of innovative service products with new features and attributes [2], so service products are comparable to tangible products [1]. The S-D logic, in contrast, focuses on the processes of serving, rather than on output in the form of a product offering [24]. Here, the value of an innovation is not delivered to the customer as a product but can offer a promise of value creation—that is, value propositions. Customers approve these propositions by engaging with the firm's service process, thereby cocreating value with the firm [45]. Service innovation, then, is the creation of value propositions, which are generated when firms deliver resources (e.g., information, knowledge, skills) to improve the customer's

own value creation. Organizations therefore renew their service-delivery processes to provide new value propositions to their customers [45], and this renewal becomes the essential source of service innovation.

Service innovation can range from incremental to radical [33, 45] and can be described along dimensions of innovation (i.e., provision of new service), changes in the client interface (e.g., intuitive design of web pages), the service delivery system (e.g., processes of service workers), and technology (e.g., new digital platforms for innovation) [7]. Changes along these dimensions involve information technologies, and studying service innovation in contemporary organizations requires that we attend to the specific role of materiality. The relationship between materiality and humans is increasingly dynamic, requiring an emphasis on relationality, materiality, and performativity [34]. The use of information technology reconfigures how humans enact practices, and entirely new practices emerge: "Material-discursive practices redraw boundaries, changing inclusions/exclusions, and making a difference in who participates, how, and with what consequences" [34, p. 214]. Practices are clusters of recurrent human activities that are informed by social and contextual relations [39, 40]. In addition to new human-discursive practices, digital technologies can allow for service automation, for instance, through recommender systems [55]. Notably, IT-enabled service innovations are grounded in the flexible, reprogrammable nature of digital technologies [58].

Against this background, we seek to examine how BDA technologies enable service processes that create value propositions for customers. In doing so, we focus on the roles of materiality as well as human actors. Next, we turn to the class of digital technologies on which we focus: BDA.

Big data and big data analytics

Technological advancements in the tools and methods of business analytics provide unprecedented access to vast amounts of data beyond the firms' business transactions—big data [4, 28]. "Big data" describes data that are "generated from an increasing plurality of sources, including Internet clicks, mobile transactions, user-generated content, and social media as well as purposefully generated content through sensor networks or business transactions such as sales queries and purchase transactions" [14, p. 321]. Scalable techniques (e.g., text analytics, web analytics) enable firms to process and analyze such trace data—digital records of activities and events that involve information technologies [18]—from, for instance, websites and social media, including users' online activities (e.g., browsing and purchasing patterns) and online conversations (e.g., opinions, feedback, and sentiment regarding a product or firm). Firms also use data trails from digitized objects like sensor-equipped mobile phones and other devices. Web-based and sensor data are generated in high volumes (large-scale data), at high velocity (high-speed data), in wide variety (e.g., text-based data and numerical data), and with a high level of veracity [28]. Table 1 provides an overview of key BDA technologies.

The huge amount of information about customers from sources that reside inside and outside the firm provides a critical source for innovation in general and a variety of

Table 1. Key BDA technologies

BDA technologies	Description
API	Provides access to data sources like sensor data, clickstream data, and social media data [3]
Data lake	Stores data in its native format until it is needed; used in combination with, for example, a Hadoop framework, this technology allows firms to analyze large and/or unstructured data much faster than relational data warehouse systems do [37]
Stream analytics	Analyzes streaming data in real time in order to identify patterns and trends and/or to detect current and/or future deviations from normality [53]
Web analytics	Analyzes clickstream data logs to provide insights on customers' online activities and reveal their browsing and purchasing patterns [3]
Mobile analytics	Analyzes clickstream data logs and sensor data (e.g., location data) generated by mobile devices to provide insights on customers' mobile activities and movement patterns [3]
Social media analytics	Analyzes social media data (e.g., user posts) to provide insights on customers' activities, sentiment, opinions, and preferences [3]
Predictive analytics	Uses statistical techniques to analyze current and historical facts to make predictions about future events and/or behaviors [3]
Rule-based system	Applies predefined sets of rules to initiate actions based on the interaction between input and the rules [53]
Visualization application	Transforms the results of data analytics into visually comprehensible and customizable dashboards [3]

opportunities for service innovation in particular [38, 49]. Insurance firms, for instance, offer customers electronic data recorders (EDR) for use in their cars to collect detailed information on how they operate their vehicles (e.g., average speed, use of brakes) and to provide the lowest rates to the safest drivers [31]. To capitalize on these opportunities for innovation, executives must understand BDA technologies and their transformational impact in order to choose the appropriate applications and analytical models that address their specific business needs. But what is the potential of BDA technologies in specific contexts of use with specific objectives, such as service innovation with the aim to create customer value? Next, we discuss the concepts of materiality and affordances, which provide a lexicon with which to theorize about how the material features of digital technologies are complicit in accomplishing change [21].

Materiality and affordances

Materiality refers to those properties and features of information technology artifacts (e.g., IT infrastructures, software systems, specific algorithms) that have some stability across contexts and across time [22], and that are also described as "continuants" [10]. Therefore, we identify the materiality of BDA technologies in terms

of hardware, that is, physical materiality, and software, that is, digital materiality [24, 58]. Examples include in-memory technologies, data lakes, and software packages like Python and R that allow for predictive analytics.

Just how do the material features of digital technologies allow for innovation? The concept of affordance has become the predominant way to theorize about the action possibilities provided by the material features of information technology (e.g., [12, 25, 26, 21, 42, 59]). Affordances are potentials for actions that arise from the relationship between technical objects (e.g., the materiality of BDA technologies) and goal-oriented users or groups of users [26], such as organizations that seek to innovate their service. Users and user groups interpret technical objects in light of their objectives, which are influenced by the organizational context, including strategies, customers, competitive environment, values, and regulations [23, 42]. As affordances describe the potentials for action, they must be enacted or actualized to result in observable outcomes like service innovations [12, 21, 47].

The concept of affordances has been used in a variety of individual and organizational contexts. The material features of business process management tools and dashboards, for instance, afford the visualization of entire work processes [59]; features of knowledge sharing, acquisition, maintenance, and retrieval afford virtual collaboration [59]; interaction and information access features afford organizational sensemaking [42], and structured data-entry forms and common databases afford the capture and archiving of digital data about patients in health care [47].

In this study, we ask what BDA technologies afford if they are interpreted by organizations that seek to generate new value propositions for their customers as they draw on an S-D logic. It is against this background that we conducted our qualitative case studies, where the concepts of materiality and affordances served as analytical lenses through which to investigate how the material features of BDA technologies afforded service innovation in the case organizations as they interpreted BDA in light of an S-D logic.

Research Method

Because empirical evidence on the impact of BDA on service innovation is scarce, we employed an exploratory, multisite case study approach to develop a model that is firmly grounded in the analysis of data. The phenomenon of interest is an emergent phenomenon that has previously not been subject to in-depth empirical investigation, so we sought revelatory cases [8]. Despite the growing literature on BDA, there is currently no empirically based theoretical model that explains how BDA enables service innovation. In conducting our multiple case studies, we followed established guidelines for case study research (e.g., [9]). While our research process was exploratory, we were sensitized by the concepts of materiality and affordances to analyze what material features of BDA afforded the case organizations' service innovations. While we used this abstract framework, we remained

open to the emergence of other concepts and relationships. For example, through this process we found that BDA technologies afforded service innovation in two ways: service automation and IT-supported service delivery by human service actors (i.e., human-material service practices); that is, the technology afforded human service actors new actions that led to fundamentally revamped practices.

We took several measures to corroborate our findings and ensure credibility, transferability, dependability, and confirmability, which are important measures of the trustworthiness of findings from qualitative research [52]. First, in order to ensure credibility, we triangulated across sources, methods, and researchers, and we debriefed with peers and participants. Second, to ensure transferability (i.e., the extent to which the interpretation can also be employed in other contexts), we triangulated across sites through purposive sampling, looking for the occurrence of phenomena across case sites, as well as for differences. Third, to ensure dependability (i.e., the consistency of the interpretation over time), we met with respondents over time, and we aimed to explain change. Finally, to ensure confirmability (i.e., the researchers' objectivity in interpreting findings), we triangulated across researchers by involving two researchers in conducting interviews with key respondents to avoid subjectivity and preconceptions. Moreover, data were analyzed by the first and second author independently. The results from this analysis and the coding decisions were discussed with coauthors, who contributed to the conceptualization of findings in terms of a coherent, integrated theoretical scheme. This approach led us to go back and forth between data analysis and theory development, and thus firmly ground our theory development in empirical data.

Site selection

We applied literal replication logic to purposefully select case organizations that we expected to yield similar results [35]. The cases have a number of common characteristics with regard to ownership, relevance of BDA to service innovation, and cultural proximity. They are all B2C firms that operate in industries with considerable experience and expertise in the collection and analysis of large amounts of customer data: insurance, banking, telecommunications, and e-commerce. All of the case organizations consider service innovation to be strategically important, as competitive pressure and changing customer behavior have led them to recognize the need to improve how they serve their customers through new value-creation opportunities and competitive differentiation. The case organizations see significant potential in BDA for service innovation and have performed concrete projects. To limit cultural differences, we sampled cases from Austria, Germany, and Switzerland, countries that have significant cultural commonalities.

Aside from these commonalities, we sought to obtain a sample of firms that are diverse in terms of industry, size, and BDA maturity. The use of BDA technologies in these firms ranged from full-blown BDA solutions that use, for instance, data

Table 2. Overview of case organizations

	Company A	Company B	Company C	Company D
Country	Switzerland	Switzerland	Austria	Germany
Industry sector	Insurance	Banking	Telecommunications	E-commerce
Number of employees	4,000	20,000	8,600	1,700
Turnover in 2015	US$11.0 billion	US$28.0 billion	US$2.8 billion	US$1.0 billion
Big data vision	Increase customer centricity and the firm's position as a digital leader	Provide efficient but high-quality personal advice	Enhance core business by offering excellent individual service at all contact points	Tailor customer interactions and extend the service value chain
BDA technologies	Full-blown BDA infrastructure with data lake and in-memory technology	Full-blown BDA infrastructure with data lake and in-memory technology	High-performance data warehouse; predictive analytics	High-performance data warehouse; web and mobile analytics

lakes and in-memory technology (in the cases of the insurance and the bank firms), to limited solutions that use, for instance, web and predictive analytics (in the cases of the telecommunications and e-commerce firms). Choosing cases from four industries allowed us to compare the cases for commonalities and differences, and to identify BDA-enabled service innovations that are not industry- or firm-specific. This approach enhances the analytical generalizability of our findings [35]. Table 2 presents an overview of the four cases.

Data collection

We used semistructured interviews as our primary data source—an approach that is appropriate for gathering rich, empirical data, particularly when the phenomenon under examination is episodic and infrequent. From each case firm, we sampled six to eight participants, whom we selected through purposeful sampling; that is, we chose respondents whom we expected would provide information that was relevant to our theory development [35].

For each case site, we first established a relationship with a C-level manager in the firm as the main point of contact. We briefed this person about the research project through a written project summary and a telephone call. Suitable respondents in each firm were then selected jointly by the manager and the first and second authors of this study. The principal criterion for selecting respondents was their knowledge about BDA use at the case firm and its application in the firms' service innovation. We chose experts from several functional areas, as the use of BDA for service innovation involves multiple business units. We conducted 30 interviews with both market (e.g., marketing, sales) and technical experts from a variety of functional areas and hierarchical levels to learn about the relationship between the material features of BDA and what they allowed for in terms of service innovation (Table 3).

The interviews were based on a set of open-ended questions that allowed us to follow up on interesting and unexpected responses and that left the participants free to elaborate on their perceptions, experiences, and reflections [35]. Prior to asking the questions, we introduced the goals of our study and the goals of the interview. The questions were guided primarily by three key issues: (1) the participants' understanding of big data and BDA in order to ensure a common understanding of the concepts under discussion, (2) the relevance of customer orientation and service innovation at the case organization, and (3) how BDA contributes to service innovation and improvement in the firm. Participants with technical backgrounds were asked additional detailed questions about current IT infrastructures and the role of BDA technologies in their organizations. The interview protocol is shown in the Appendix. The interviews lasted between 45 and 90 minutes and were recorded and transcribed verbatim so we could analyze the resulting data in a rigorous and transparent manner. Interviews and transcriptions were done in German, the participants' native language, and native German speakers conducted all data analyses. The

Table 3. Interview partners

Firm	Interview number	Participant's position	Interview number	Participant's position
A	1	Head of Digital Business	5	Head of Data Analytics
	2	Head of Sales Applications	6	Big Data Architect
	3	Head of Community Management	7	Project Manager
	4	Head of Digital Innovation	8	Transformation Manager
B	1	Head of Strategic Marketing	5	Solution Architect
	2	Head of Digital Innovation	6	Senior Manager Big Data
	3	Head of Customer Management	7	Head of IT Architecture
	4	Head of Online Communication	8	Head of Big Data
C	1	Chairman of the Board	4	Head of B2B Service
	2	CEO	5	CTO
	3	Head of Sales and Marketing	6	Head of Analytics
D	1	Senior Manager Business Strategy	5	Senior Manager of CRM
	2	Manager Business Strategy	6	Head of Business Intelligence
	3	Head of Business Operations	7	IT Project Manager
	4	Head of CRM	8	CTO

resulting coding and quotations were translated into English for presentation purposes.

Additional data in the form of publicly available company information (e.g., annual reports, press releases) and internal presentations provided background information on the BDA infrastructures, data strategies, and current practices that were related to service innovation. These documents helped us further clarify the information gathered during the interviews and provided valuable ancillary information about the organizational context—that is, the firms' strategic objectives, customers, competitive environments, and regulations.

Data analysis and theory building

The data analysis process broadly followed the recommendations of Eisenhardt [9], Paré [35], and Yin [56] for within- and cross-case analyses. First, we analyzed each case as a separate study so we could focus on the collected case data and understand

each case's unique patterns. In a second step, we aggregated the findings of the within-case analyses in order to determine whether they made sense beyond each individual case [9, 35]. The within-case analysis and cross-case analysis, as well as the coding and analysis we applied, were conducted in a manner that allowed us to move back and forth between the analysis of empirical data and theorizing, so the steps we describe here are not strictly sequential phases.

Within-case analysis

In the initial step of the data analysis process, we read the interview transcripts and noted our first impressions in interview and case reflection memos [29]. Memo writing continued throughout the entire data analysis process so we could keep track of our reflections, comments, questions, and ideas as they occurred and store them for further investigation and refinement. We then coded the case data (i.e., interview transcripts, and documents) using the qualitative data analysis tool ATLAS.ti, which enabled us to store all our data in a central location, analyze it, and maintain traceability of the coding. Each case was treated as a separate study, and each step was conducted independently by the first and second author, with regular discussions to avoid subjective interpretations and enhance validity.

In coding the case data, we first used open coding [46] in order to identify concepts that were related to the use of BDA for service innovation that were salient in the data,[3] while remaining as open and unconstrained by prior theory as possible. During this stage, we frequently compared the interviewees' responses in an effort to group answers that pertained to common codes and to analyze different perspectives on emerging codes. The process of open coding generated an initial list of more than 300 descriptive codes (e.g., goals like "identifying changes in the state of customer's house," "identifying customer's wedding") that were further grouped and integrated in order to derive more abstract categories (e.g., the open codes "identifying changes in the state of customer's house" and "identifying changes in the state of customer's car" were objectives that were grouped under the more abstract category of "identifying changes in the state of relevant objects.")

When no new concepts emerged, we conducted a coding stage similar to axial coding [46], where we organized the categories identified using the analytical framework of materiality and affordances; that is, we looked for the use context in terms of organizational goals and the service innovations that were afforded by the material features of BDA technologies. The concepts of materiality and affordances were appropriate theoretical lenses, as we saw that, indeed, BDA technologies afforded service innovation as material features of BDA were interpreted in light of new action goals related to creating improved service delivered through both human agency and material agency. By considering material features as well as what these features allowed for when they were interpreted under an S-D logic, we were able to establish links between the material features and specific service innovations.

We compared the coders' results, discussed differences and commonalities, and merged the results.

Cross-case analysis

After analyzing the data in each case, we used cross-case analysis to identify cross-case patterns and determine whether the findings of the within-case analyses were applicable across the cases [9, 35]. We analyzed the cases' similarities and differences regarding the material features and what they afforded to identify patterns across the cases. We discussed the differences, focusing on the reasons that these differences occurred, and learned to what extent the cases were comparable. Then we compared the patterns for consistency and aggregation, discussed our conclusions, and refined the patterns, which helped us move toward the integrated theoretical scheme that was emerging from our analysis.

Next, we describe our analysis of the four cases using our lexicon of materiality, affordance, and human and material agencies, and then present a theoretical model of BDA-enabled service innovation.

Case Analysis

Company A: Insurance

Case organization A is the Swiss subsidiary of a multinational insurance firm that offers private individuals and corporate customers a broad range of personal, property, liability, and motor vehicle insurance. A decade ago the company was focused on the core insurance business of selling insurance policies and paying bills on time, but now it aims to increase its customer orientation and to change its role from "payer" to "player" by taking a more proactive stance in engaging with its customers. These strategic objectives translated into how the firm innovated its service processes, as it envisioned increasing its customer centricity so customers would feel they were in good hands before and in the event of damage, and improving its customer interaction beyond handling insurance claims. Accordingly, the firm sought to provide support to customers by meeting their needs at the right moment.

As part of the firm's overall strategy to become more customer-centric, the firm implemented advanced BDA technologies, including in-memory technology and a data lake with a Hadoop framework that allowed it to store data in a central location and analyze data from a variety of sources with reduced latency. Trace data were gathered from internal sources (e.g., the firm's website, mobile apps) and external sources (e.g., social media, price comparison portals, digitized objects like sensor-equipped homes and cars). The company used several analytical applications, including stream analytics for analyzing sensor-based data streams in order to recognize insurance-related events (i.e., deviations from a normal state) and to initiate appropriate actions in real time using rule-based systems. The firm also

applied web and social media analytics and predictive analytics in order to recognize and anticipate insurance-related changes in the customer's life at an early stage.

As the company pursued its goal of providing customer support at the right moment, the material features of BDA enabled the implementation of two types of service innovation: automation of certain customer service-related processes in a way that facilitated the individualized interaction with customers in real time, and opportunities for employees to engage in new service-provision practices like proactive advice. Thus, the material features of BDA in response to new strategic action goals afforded automation and new human-material service practices. Consider two examples.

First, stream analytics facilitated the automated, real-time recognition of insurance-related events in, for instance, the customer's home (e.g., open window, burglary) or car (e.g., accident). These material features afforded automated trigger-based service actions on the customer's behalf. For example, the detection of a forced entry into the customer's home automatically triggered predefined actions in real time, such as starting an alarm or calling the police, potentially preventing loss:

> We are trying to expand our business and think innovatively. . . . As people are increasingly building connected objects into their homes, we are thinking about how to offer a service in terms of security. . . . If you build such a connected protective shield around the house, then it must work reliably in real time. (Respondent 2, Company A)

The automation of customer-related processes enabled the company to provide an entirely new kind of service—damage prevention and support. While the insurance firm previously got involved only after the damage had occurred, this service innovation improved customers' sense of well-being and security.

In the second example, the insurance agents were afforded entirely new ways of engaging with customers such that they proactively approached them with individualized information, products, or service at the right time. The material features of BDA, particularly web and social media analytics, as well as predictive analytics, facilitated the recognition and prediction of major lifetime events (e.g., marriage, property purchase, starting a family) that indicated changed insurance needs. For instance, the firm gathered and analyzed clickstream data from related third-party websites, price-comparison portals, and the social-media data of customers who were connected to their insurance agents through social networking sites. Visualization applications (i.e., dashboards) gave the insurance agents information about identified or predicted triggers so they could approach their customers with appropriate service offerings in a timely way:

> We recognize a customer's lifetime event and, after a while, the customer receives information [related to that event]. What we want to achieve is [using] an event . . . in order to react immediately to the customer's current situation. (Respondent 3, Company A)

This support was in the form of new human-material service practices. In these cases, insurance agents still had to make their own decisions about how to address the specific events; that is, the employees' skill sets, experiences, and customer contact strategies interacted with the material features of BDA to create new practices. This fundamentally revamped how service was delivered. Previously, insurance agents had no (or only limited) access to information about customers' lifetime events (e.g., through their personal social networks), so service provision was primarily reactive to customers' requests:

> It used to be the decentralized insurance agents who went through life with open eyes and who saw that, for instance, a woman was expecting a child. It was the human sensor that brought the information. As the business and its services become more digitized and the customer increasingly communicates with us via digital channels, we have more information to find these magic moments digitally. (Respondent 1, Company A)

The new, innovative practices served the individual customer at the critical moment, thereby increasing the relevance of product and service offerings and creating a sense of convenience.

To summarize, the insurance company used several BDA technologies in two ways. First, BDA allowed for service automation, taking action on the customer's behalf based on triggers (material agency). Second, BDA technologies afford human service actors to serve the customer based on lifetime events and adapting the customer contact strategy accordingly (human and material agencies). This approach changed how the firm served its customers by facilitating its ability to provide proactive service (either automatically or via human interaction) tailored to the individual customer's needs. Table 4 provides an overview of how the company's

Table 4. BDA-enabled service innovation at Company A

Organizational goals	Material features of BDA	BDA-enabled service innovation
Provide tailored service to customers at the right moment	• Sensor data • Data lake • Stream analytics • Rule-based systems	Automatically taking action on the customer's behalf in response to triggers (material agency)
	• Clickstream and social media data • Data lake • Web and social media analytics, predictive analytics • Visualization applications	Approaching the customer in response to triggers (i.e., lifetime events) through a human service actor who adapts the contact strategy to the customer's individual needs (human and material agencies)

organizational goals translated into the provision of automated and human-material service, afforded by the material features of BDA technologies.

Company B: Banking

Case organization B is a leading global financial services firm and one of the largest full-service banks in Switzerland. The firm has a strong position in retail banking for private customers and wealth management for high-net-worth individuals. One of the firm's key strategic objectives was to further improve its provision of first-class financial advice and solutions. The use of digital technologies, including BDA, was an important pillar in implementing the bank's strategy of improving service provision and offering a unique customer experience. Against this background, the firm had implemented an omnichannel strategy in retail and wealth management, integrating its offline (i.e., branches, personal bank advisers) and online channels (i.e., online and mobile banking) and allowing customers to choose their preferred interaction channels, which were customized to their needs and habits. The online channels were not intended to substitute for the offline channels but to support personal advice, which the firm's customers expected because of the nature of the financial products. Accordingly, the firm sought to provide a convenient and highly individualized customer experience and a consistent and seamless customer journey across all channels.

In an effort to realize these objectives, Company B made significant investments in an advanced BDA infrastructure that included in-memory technology and a data lake, combined with a semantic knowledge base using open-source software. This infrastructure made it possible to complement traditional data sources (e.g., transaction and customer relationship management [CRM] data) with previously unavailable data sources, including new internal data sources like the firm's website, its online and mobile banking portal, and unstructured data generated from business-related interactions between customers and the firm (e.g., e-mail, letters). Various analytical applications facilitated the identification of patterns in the data, including web and text analytics. Moreover, based on a data discovery workbench, data scientists developed algorithms and statistical models for analyzing the variety of data stored in the data lake.

As the company followed its new goals in terms of providing a convenient and individualized customer experience, and offering a consistent and seamless customer journey, the material features of BDA allowed it to implement service innovation in two ways. First, BDA technologies allowed it to automate the customization of content that was provided through digital channels. Second, BDA technologies provided employees opportunities for engaging in new service practices in terms of highly individualized and consistent customer support. Consider two examples.

First, the newly available material features of BDA, particularly web analytics, allowed for the real-time recognition of business-related events on digital channels. For instance, the detection of a certain user behavior on the e-banking portal based on clickstream data,

combined with insights from historical customer data, automatically resulted in the display of an appropriate message that addressed the customer's anticipated needs:

> In e-banking, they [the campaigns] are quite specific because we measure the customer's behavior. We analyze the logs and compare them with the history. For example, a young man suddenly uses our mortgage calculator. We see this, of course, and then say: this is a young man who has never clicked on this before and now he has been doing it for three, four weeks or even two months. He is probably interested in a house. This might be a good moment to approach him and say: "Come in and talk with us. If you are interested in a mortgage, we can advise you in this way." This is much more individualized than the approach where the customer is 40 to 50 years old, or these are all students; let's offer them a credit card. (Respondent 8, Company B)

The firm used BDA technologies in a way that enabled them to customize user interfaces (e.g., provide tailored content) automatically. Compared to their previous process, the new process did not base content on general customer segmentation criteria but adapted the content to observed customer activities combined with historical data. Therefore, it was highly individualized.

As for the second example, personal bank advisers and service employees were afforded new individualized ways of interacting with customers considering their customers' preferences. The material features of BDA allowed for collecting customer data from multiple new and traditional data sources, storing it in the data lake, and compiling a rich and up-to-date customer profile. Visualization applications (i.e., dashboards) provided insights for the advisers and service employees, allowing them to cater to their customers' individual preferences when they interacted with them:

> It is about gaining a holistic view of the customers. . . . The great driving force and the keyword that drives us to know more about the customer is precisely this multichannel idea: we want to know what the customer is doing outside [the business relationship]. While once this view was never consistent and we did not know it, now we start to learn more about the customer, including her activities and behavior outside [the business relationship]. We also consider how this information is delivered to the personal adviser or call center agent and what we do with this data—how we use it to interact with the customer. It is very important that we record and understand the data in a way that allows us to improve how we speak with the customer. (Respondent 5, Company B)

The customer profile informed employees about a customer's prior interactions with the bank, allowing for a seamless customer journey such that, if the customer initiated a process in one channel (e.g., on the e-banking portal), it could be taken up by another channel (e.g., a personal consultation conversation with the adviser). Employees were also given concrete recommendations for action based on the customer's preferences. For instance, they were instructed on topics that should be

Table 5. BDA-enabled service innovation at Company B

Organizational goals	Material features of BDA	BDA-enabled service innovation
Provide individualized and consistent service at all touchpoints	• Clickstream data, historical customer data • Data lake • Web analytics, predictive analytics • Rule-based systems	Automatically customizing user interfaces (e.g., providing tailored content) in response to triggers (material agency)
	• Digital trace data from various sources compiled in the customer profile • Data lake • Predictive analytics • Visualization applications	Interacting with the customer in accordance with the customer's preferences, as derived from previous interactions and behavior (human and material agencies)

addressed during consultation or were informed about the customer's preferred interaction channel. In these cases, the customer profile provided additional support for employees in their efforts to interact with the customer in a customer-centric manner. Employees still had to make their own decisions on how they used the information and how they adapted their behavior, so the customer's profile and the employee's skill set and experience worked together.

To summarize, Company B used several BDA technologies in two ways. First, BDA allowed for service automation, for instance, customizing user interfaces based on triggers (material agency). Second, BDA technologies provided employees with comprehensive information on a customer's profile and history so employees could adapt the customer interaction to the customer's preferences (human and material agencies). Company B was enabled to provide highly individualized customer support and a consistent customer journey along all touchpoints. Table 5 provides an overview of how the bank's organizational goals translated into service innovation.

Company C: Telecommunications

Case organization C provides private and corporate clients with telecommunication services. The company operates its own mobile network and distributes products in the areas of fixed net, mobile voice, Internet, and TV. As a full-service provider, it also offers corporate clients cloud and machine-to-machine service. An infrastructure provider, the firm sees itself as an enabler of digitalization by offering high-quality networks in terms of availability, performance, and security. In the B2C sector, the company operates in a mature market, so it sought new ways to increase revenues and profits. While competition in the telecommunications sector had for a long time

been driven by price and product, customer experience became the key brand differentiator. Therefore, in order to enhance their core business, the firm wanted to offer excellent individual service at all contact points to retain and create loyal customers. Accordingly, Company C sought to provide the product offering or problem solution that was most relevant to each customer.

The firm operates a modern and flexible analytics infrastructure that draws on an enterprise data warehouse that centrally stores large amounts of customer data (e.g., how and where subscribers use their phones) and data from network equipment and server logs. The analysis of customer data (e.g., demographic data, use patterns, browsing behavior from clickstream logs, and call center contacts) allowed the firm to generate a detailed profile of each customer and her needs.

We found evidence of one type of BDA-enabled service innovation in this firm. BDA technologies provided affordances to employees for engaging in new service practices, particularly preference-based support. In contrast to Case A and Case B, we found no evidence of automation. New human-material service practices emerged in response to strategic action goals offered by the material features of BDA. Consider the following example.

Sales and service employees (i.e., shop assistants and call center agents) were afforded entirely new ways of engaging with customers. They could convey the right message, make the right offer, and choose the right level of service during every customer engagement so every customer had an individual customer experience. The material features of BDA allowed for the recognition and anticipation of customer behavior by applying statistical models (e.g., predictive analytics) to the past interactions, usage, and purchase behavior that were compiled in individual customer profiles. The analyses resulted in concise, clear, and timely metrics on, for example, calling patterns, data consumption, and customer satisfaction. Moreover, recommendations for the next best actions (e.g., the most suitable offer, problem solution, or interaction channel) were derived and provided to the frontline employees through a uniform visualization application. Thus, employees were equipped with timely, actionable insights about the customer's history and anticipated behaviors and given decision support at the point of customer interaction. As a result, they were able to cater to the customer's individual preferences while engaging with that customer:

> It's about anticipating . . . from the data—the human-like, the empathic. This is exactly what makes the difference to the customer, whether it is genuine or artificial. Empathy, in the case of a firm, means that it can put itself into the customer's shoes, know what she wants next. I think that is what differentiation must be all about because the rest is more of the same. (Respondent 3, Company C)

Guided in their decisions and customer interactions, sales and service employees applied their personal skill sets or experiences to incorporate the available information into their service practices. The new practice fundamentally changed the firm's service delivery, as previously frontline employees had limited visibility of their

Table 6. BDA-enabled service innovation at Company C

Organizational goals	Material features of BDA	BDA-enabled service innovation
Provide the product offering or problem solution that is most relevant to each customer	• Digital trace data from various sources that is compiled to a customer profile • Data warehouse • Predictive analytics • Visualization applications	Interacting with the customer in accordance with the customer's preferences derived from previous interactions and behavior (human and material agencies)

customers and could react to customer requests only on the spot, mainly based on the company's guidelines and their intuition. BDA technologies enabled the agents to optimize their service practices by providing them with the contextual information they needed to engage with their customers in a way that was sensitive to their customers' preferences.

To summarize, BDA technologies at Company C provided employees with comprehensive information about a customer's profile and history, enabling them to adapt their interactions to the individual customer's preferences (human and material agencies). Table 6 provides an overview of how the telecommunications company's organizational goals translated into human-material service practices that were enabled by the material features of BDA technologies.

Company D: E-Commerce

Case organization D is a leading online provider in the German travel sector. It operates several websites that cover the entire travel-booking cycle, from weather forecasts to flight and hotel portals to rental car bookings. In line with the websites' transaction-based business model, the firm sought to increase growth through four key levers: traffic, conversion, cross-selling and up-selling, and retention. In addition, Company D sought to increase the efficiency of its communication activities by decreasing wasted coverage. It operates in a highly competitive market with a large number of competitors that offer similar or even the same products with a high level of price transparency. In order to attract customers and gain market share, the common practice was to offer the lowest price. However, in recent years, Company D began to pursue customer-centrism, placing a stronger focus on service differentiation, instead of pricing only, in order to deliver a superior customer experience and gain customer loyalty. Accordingly, it sought to improve its customer interaction through individualization of its user interfaces and to extend the service value chain by also serving the customer beyond the booking.

To achieve these objectives, Company D applied BDA technologies to continually analyze how customers interact with their websites and mobile apps. Web and mobile analytics provided insights into users' online activities enabling the company to better understand their browsing and purchasing patterns. For example, when a customer visited one of the firm's websites, clickstream data were generated through cookies and logged in a database for web log analysis. These activities were supported by web analytics tools like Google Analytics. Company D ran a high-performance data warehouse to store data from multiple sources centrally, which allowed data scientists to conduct analyses. Based on the insights gained through web and mobile analytics, rule-based recommender systems automatically created targeted product- and service-related suggestions that had a high probability of meeting customer needs. Moreover, the firm used location-aware analysis of sensor data from smartphones to provide context-aware content through its mobile apps. The firm emphasized measuring users' responses (e.g., e-mail open and click-through rates from mail campaigns and newsletter) in order to continuously learn about customers' preferences and improve its targeting in the future:

> You open the response data and see "yes, it worked. We caught her." This then goes back to the data warehouse, where the database is updated and the algorithm is optimized. In this way, we build a small circuit. For me, this is data-driven marketing to the extent it is currently possible. (Respondent 4, Company D)

As the company followed its new goals in terms of improving customer interaction, and extending the service value chain, material features of BDA allowed it to implement a strategy of improving customer service processes through automation. First, BDA technologies allowed to automate the adjustment of user interfaces. Second, BDA technologies supported the establishment of additional touchpoints before and during the customer's travel. Consider two examples.

First, BDA enabled the firm to adjust user interfaces automatically in terms of the types and order of the travel options presented, their visual appearance, and recommendations for complementary products and services. Instead of presenting the same user interface to all customers, it was adjusted to the customer's individual characteristics:

> The other aspect is the personalized appearance of websites. At the moment, the online business is rather one-size-fits-all. This means I see the same website you do, although you and I are completely different target groups. I am male and live in Munich. You are female and live in Switzerland. Why should you get the same website as I do? This topic—the personalized delivery of UI [user interface] and UX [user experience] concepts and personalized website creation—is of great importance to us. (Respondent 3, Company D)

Predictive analytics facilitated the combination of historical behavioral patterns and current navigation behavior in order to predict the probability that the customer would buy certain products. This approach allowed the firm to display related products (e.g., offering museum packages to a customer with a history of traveling

to cultural sites) when the customer processed a transaction. Providing an individualized customer experience enhanced convenience by helping customers find appropriate offers much faster:

> I believe it has added value for the customer because he gets only the offer that really interests him. He does not need to search for three hours because we already know what he wants, so this makes it easier. (Respondent 2, Company D)

As for the second example, BDA enabled the firm to interact with customers in an automated manner beyond the transaction on the website, based on events. For example, smartphone technology allowed the firm to monitor the customer's location during the holiday and to deliver context-specific, highly personalized messages in real time:

> If we detect the customer's current location, we can act like a kind of travel guide. Then we can tell him, "You are in London, so take a look at this tourist attraction. Keep in mind it is a weekend and there is a street festival." (Respondent 2, Company D)

Thus, the firm could interact with its customers while they were out and about, for example, looking at tourist landmarks, thereby enriching their offline experience. The firm could also extend the service value chain beyond the online world by partnering with local service providers to create new value propositions jointly.

To summarize, Company D used web and mobile analytics to improve its service provision through automation. In contrast to the other three companies, we did not find evidence of new human-material service practices. First, BDA allowed for the automated adjustment of user interfaces (material agency). Second, location-aware analysis based on sensors in smartphones enabled the firm to interact with customers in real time

Table 7. BDA-enabled service innovation at Company D

Organizational goals	Material features of BDA	BDA-enabled service innovation
Provide individualized service to customers and extend the service value chain	• Clickstream data • Data warehouse • Web and mobile analytics, predictive analytics • Rule-based systems	Automatically customizing digital user interfaces in accordance with customer preferences (material agency)
	• Sensor data • Data warehouse • Mobile analytics (location-aware analysis) • Rule-based systems	Automatically customizing user interfaces (e.g., providing tailored content) in response to triggers (i.e., a customer's current location) (material agency)

(material agency). Thus, Company D was afforded the ability to consider their customers' individual needs instead of treating all customers the same, thereby enhancing convenience. Moreover, Company D could interact with customers in a personalized manner, even long after the customers booked their travel, by offering additional service on-site, thereby extending service provision from the online to the offline world. Table 7 provides an overview of Company D's BDA-enabled service innovation.

A Theoretical Model of BDA-enabled Service Innovation

This section presents an integrated model of IT-enabled service innovation that is grounded in our analysis of the four cases. Our model explains how BDA technologies enable service innovation as organizations interpret them in light of new action goals that are related primarily to individualizing service. We identified two key types of service innovation afforded by BDA technologies: automation of customer-sensitive service provision and new human-material customer-sensitive service practices. Both types of innovation are enabled by the material features of BDA technologies in terms of sourcing, storage, event recognition and prediction, behavior recognition and prediction, rule-based actions, and visualization. When enacted, they lead to service individualization. Figure 1 visualizes this model.

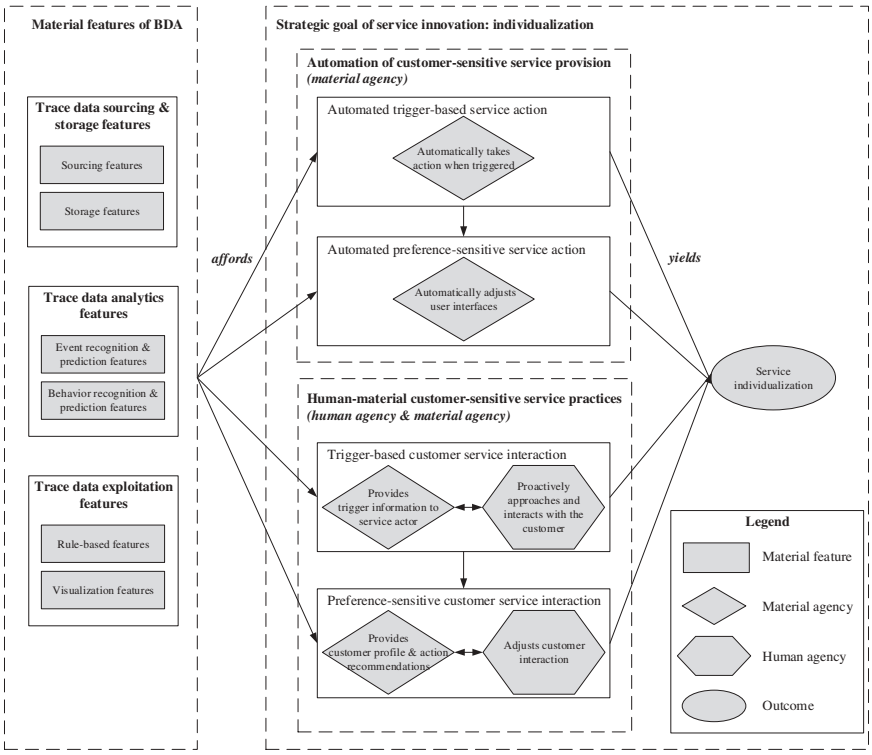

Figure 1. Theoretical model of BDA-enabled service innovation

Table 8. Service automation and human-material service practices

	Service automation	Human-material service practices
Goal	Service individualization through automated activities that are carried out without human intervention	Service individualization through interaction of the customer with a human service actor who interacts with a digital service actor
Role of agency	Focus on material agency in delivering the service	Interaction of human and material agencies in delivering the service
Nature of outcome	Deterministic provision of service	Nondeterministic provision of service: technology provides space for action

In what follows, we provide a general overview of the model and then describe its key components in terms of (1) the material features of BDA, (2) automation of service provision, and (3) human-material service practices.

By differentiating how the material features of BDA afford both service automation and human-material service practices, our model highlights how both material agency and human agency play roles in shaping organizational service processes and in creating value propositions for customers. In the case of service automation, the focus is on material agency—that is, the technology's capacity to act on its own and apart from human intervention [21]. In contrast, in human-machine service practices, human and material agencies interpenetrate in what Pickering (1995) referred to as the "mangle" of practice [36], and human agency is enacted in response to the technology's material agency [21, 51]. In the case of service automation, BDA technologies provide both necessary and sufficient conditions for service innovation, as the technology acts without the intervention of human actors. In the case of human-material service practices, BDA technologies provide only necessary conditions, as the observable practice results from the interpenetration of human and material agencies in practice. Table 8 compares the two types of service innovation.

Next, we provide detailed descriptions of the model's components, along with conceptual definitions.

Material features of BDA affording service innovation

The flexible nature of BDA technologies and their reprogrammability afford both service automation and human-material customer-sensitive service practices. BDA technologies are digital artifacts that are part of a wider ecosystem, and they derive their utility from the functional relationships they maintain [20]. Features of sourcing [3], storage [37], event recognition and prediction [53], behavior recognition and prediction [3], rule-based actions [53], and visualization [3] are built on technologies that maintain relationships and provide functions like sourcing trace data, storing trace data in databases, analyzing these data using various approaches to supervised

Table 9. Key material features of BDA technologies

BDA material features	Description	Examples of underlying BDA technologies
Sourcing features	Features for collecting and integrating digital trace data from various sources	APIs for accessing sensor data, clickstream data, social media data
Storage features	Features for storing digital trace data	Data lake
Event recognition and prediction features	Features for detecting and predicting events (i.e., deviations from a normal state)	Stream analytics, predictive analytics
Behavior recognition and prediction feature	Features for analyzing customers' behavioral patterns and predicting their future behavior	Web analytics, mobile analytics, social media analytics, predictive analytics
Rule-based features	Features for initiating automated actions	Rule-based systems
Visualization features	Features for making outcomes available to employees	Visualization applications

and unsupervised learning, and exploiting the generated insights. Table 9 provides an overview of the key categories of BDA's material features affording service individualization that emerged from our analysis.

Automation of customer-sensitive service provision

Organizations see BDA technologies as malleable technologies that afford automation of customer-sensitive service provision, consistent with new action goals related to individualized service, such as an insurance company that automatically takes action when security incidents occur. To implement service automation, organizations use algorithmic solutions that are based on the material features of BDA in terms of trace data sourcing and storage, event recognition and prediction, behavior recognition and prediction, and rule-based actions. Two types of service automation emerged as salient from our analysis: automated trigger-based service action and automated preference-sensitive service action. In the first case, the system independently carries out actions like sounding an alarm or calling the police (material agency) when triggered by an event like forced entry into a customer's home (detected by sensors), thereby, providing service at the right time. In the second case, the system automatically adjusts user interfaces, for instance, by providing tailored content (material agency) when a certain user behavior on an online channel or a customer's current location are detected, thereby, providing service in the right way. Thus, trigger-based action can lead to preference-sensitive action, as indicated in Figure 1. Table 10 provides an overview, including underlying material features and examples.

Table 10. Automation of customer-sensitive service processes

Organizational goals	Service innovation	Material features of BDA	Example
Provide individualized service to customers	*Automated trigger-based service action* describes activities that are independently carried out by a system to create value for a customer.	Features of sourcing, storage, event recognition and prediction, behavior recognition and prediction, rule-based actions	Starting an alarm or calling the police in response to a forced entry into a customer's home, as detected by a sensor
	Automated preference-sensitive service action describes activities that are independently carried out by a system to adjust user interfaces in accordance with customer preferences.	Features of sourcing, storage, behavior recognition and prediction, rule-based actions	Providing tailored content in response to certain user behavior on an online channel

Table 11. Human-material service practices

Organizational goals	Service innovation	Material features of BDA	Example
Provide individualized service to customers	*Trigger-based customer service interaction* describes the interplay of human and material agencies in providing individualized interactions with customers.	Features of sourcing, storage, behavior recognition and prediction, visualization	The system provides trigger information to human service actors who then proactively approach and interact with customers.
	Preference-sensitive customer service interaction describes the interplay of human and material agencies in providing individualized interactions with customers based on their preferences.	Features of sourcing, storage, behavior recognition and prediction, visualization	The system provides recommendations for actions based on customer profiles, which allow human service actors to adjust their customer interactions.

Human-material customer-sensitive service practices

BDA technologies afford human service actors new ways of interacting with customers, leading to human-material customer-sensitive service practices that are consistent with new action goals related to service individualization, such as proactively approaching and interacting with a customer. Two types of human-material service practices emerged as salient from our analysis: trigger-based customer service interaction and preference-sensitive customer service interaction. In the first case, the system provides service actors with trigger information (material agency), such as a customer's business-related lifetime event, after which the service actor proactively approaches and interacts with the customer (human agency). In the second case, the system uses customer profiles to make recommendations for actions (material agency), allowing the service actor to adjust interaction with the customer (human agency). Thus, trigger-based customer service interaction can lead to preference-sensitive customer service interactions, as shown in Figure 1. Table 11 provides an overview, including underlying material features and examples.

Discussion

This study presents a theoretical model of BDA-enabled service innovation that extends prior work on IT-enabled service innovation [1, 24, 34] by explaining how service automation and human-material service practices yield service individualization, grounded in the material features of BDA technologies: sourcing, storage, event recognition and prediction, behavior recognition and prediction, rule-based actions, and visualization. In this section, we discuss how our model contributes to the literature on service innovation and to the literature on digital innovation.

Contribution to service innovation scholarship

At a general level, we found that BDA allowed firms to generate customer insights and heightened awareness about customers' needs and preferences. The material features of BDA technologies facilitate firms' ability to gather and analyze the broad variety of data sources related to customers' everyday activities so firms can increase their awareness of their customers' behaviors, interests, and current situations.

Complicity of automation and human-material practices in service innovation

Our study suggests the complicity of automation and human-material practices in service innovation. Organizations follow a twofold strategy based on service automation and the implementation of new, improved human-material practices that are afforded by the material features of BDA technologies. The two are complicit in that they allow organizations to simultaneously provide their service in real time, while others still require human activity. Service automation is dominated by material

agency, while human-material service provision is characterized by the interpenetration of human and material agencies to deliver value to the customer. This view is important, considering the prevalence of and emphasis on human-material-discursive practices in the recent literature (e.g., [11, 12, 19]).

Proactive service provision

BDA facilitates proactive service provision that is based on insights into the customer and the customer's context. Service provision has typically been reactive in nature, requiring customers to approach the firm with a service request. However, digitized objects enable firms to gather and analyze data generated by the customer outside the business relationship in the customer's private sphere. Using such data to initiate timely interactions enables firms to extend their service value chains and support their customers in various life situations precisely when they need it. Being aware of customers' problems in everyday life facilitates the firm's development of new value-added service and improves the customer's experience and perception of the value the firm offers. New customer interaction points can be developed both inside and outside the business relationship, thereby increasing the frequency of interactions. This nuanced view shows how organizations create new value propositions for customers under an S-D logic [1, 24].

Speed of service provision

BDA increases the speed of service provision—even real-time service provision. For this purpose, service based on BDA is often provided through automated systems that facilitate immediate action. Prominent examples of such offerings are in the field of smart homes and telematics. By acting on events, firms can convey the impression that there is no need for their customers to deal with or to worry about such things as the safety of their homes because the firms take action on their behalf. This approach to real-time service provision is in line with the basic tenets of BDA analytics in terms of the velocity with which new data are generated and analyzed [28], and it adds another nuance to how organizations create new value propositions under an S-D logic [1, 24].

Service individualization

Enabled by insights gained into the customer both inside and outside the business relationship, service can be highly individualized and tailored to customers' needs. Instead of mass customization, BDA enables firms to tailor service cost-effectively to a "segment of one" by using knowledge gained from analyzing the customer's behavioral patterns. Based on the customer's inferred preference, a firm can automatically tailor the channel used to deliver service or the user interfaces. According to den Hertog [7]. The way the firm interacts with the customer can itself be a source

of innovation, and our analysis highlights how this way is grounded in the material features of BDA technologies that allow for interactions between human agency and material agency in delivering services. Our explanation of how BDA contributes to service innovation by providing customers with added value through individualized and convenient customer experiences contributes to the debate on personalization of information systems (e.g., [17, 48]) and to the emerging research on omnichannel management (e.g., [15]).

Our analysis also suggests that BDA-enabled service processes might be extended to address the customer on an emotional level, although such emotion-sensitive service was only mentioned in the interviews and has not been fully implemented in the case organizations. Knowledge about the customer's current or future emotional state, gained through BDA, might allow firms to adapt how they "speak" to the customer on an affective level, a phenomenon that is central to the emerging research field of emotion-sensitive technology (e.g., [16]). This field has started to design and build information systems that are sensitive to human emotions and that can change their behavior accordingly. This bears the potential to emphasize the "human component" in increasingly electronic and automated customer interactions and highlights the role of human agency in service delivery. Such emotion-sensitive service processes promise to deliver emotional or hedonic value, such as by providing customers with a positive feeling when they interact with the firm, thereby enriching and deepening the customer's experience.

Contribution to digital innovation scholarship

Digital technologies are reprogrammable [20, 58], so organizations explore configurations of technologies that form functional relationships to identify new potentials for action as they are confronted with new action goals. Our analysis shows that BDA technologies are an example of such malleable, flexible digital technologies and that, in order to innovate service, organizations should capitalize on the combined effects of technologies that are related to sourcing, storing, analyzing, and exploiting data. Technology is reprogrammed in some cases to automate service processes and in other cases to provide actionable spaces to human actors, leading to novel interpenetrations of human and material agencies. Our study suggests that reprogrammable digital technologies allow for innovations that are shaped by material agency and the interpenetration of human agency and material agency.

The concept of affordances helped us explain how this digital innovation occurred. Affordances are both dispositional (i.e., associated with the technology) and relational (i.e., in relation to a specific use context) [12]. As the use context changes, new, innovative applications of digital technologies emerge [41]. As our analysis of four cases from different industries suggests, these innovative affordances occur across contexts. But what explains the similarities in the occurrence of innovations across contexts? There have been advances to theorize about how such regularities occur, for instance, using arguments that draw on institutional theory [19, 41] or

concepts like habit [12] or performativity [5]. Our study highlights how BDA gives rise to similar innovative affordances across our case organizations, as these organizations draw on an S-D logic, even though these similar applications are grounded in different technologies. While one company might use, for instance, Hadoop, as was the case in Company A, another company might use a different technological platform. Still, we were able to identify the material features of those technologies at an abstract level and can explain the similarities by means of the prevalence of an S-D logic, where organizations seek to implement customer centricity and service individualization. This explanation is consistent with the view that the identification and enactment of technology affordances is shaped by the institutional context and associated logics on which an organization draws [19, 41].

This view suggests that the same technology might be reinterpreted in such a way as to afford new actions in light of new action goals. The argument is that malleable digital technologies are (1) (re-)interpreted in light of changing action goals, (2) that this (re-)interpretation leads to certain development and implementation activities that enable new functional relationships among the material features of digital technology, and that (3) these new relationships afford new configurations of material and human agencies. In this view, affordances are at the organizational level (e.g., [42, 47, 59]). Therefore, our work is in line with work that has recognized the observable regularities in the enactment of information technology across contexts and time [13, 41]. Information technologies are used in strikingly similar ways across organizations, which is also the case for BDA-enabled service innovation.

Implications for IS Research and Practice

Implications for research

Our study highlights how BDA technologies enable service innovations and, thus, contribute to creating new value propositions. In so doing, the study adds an integrated perspective on IT-enabled service innovation in organizations [34]. Our research identifies material features of BDA technologies in terms of sourcing, storage, event recognition and prediction, behavior recognition and prediction, rule-based actions, and visualization—a conceptualization that accounts for both the retrospective and the prospective (e.g., in terms of predictive and prescriptive analytics) characteristics of BDA [44]. Moreover, instead of treating BDA as an undifferentiated whole, our empirical results support the notion that BDA consists of the interplay of multiple applications for gathering, storing, analyzing, and communicating big data from external and internal data sources [3], highlighting the functional relationships among digital artifacts [20] and their combined potential for service innovation [58]. We also highlight how this materiality translates into both automation and the provision of human-material service practices, a perspective that can inform future research in four primary ways.

First, our theory development suggests that future research should consider the potential of BDA technologies in developing service automation and human-material service practices. Automation can relate to both automating existing service practices and implementing new automated processes that were once impossible. Similarly, human-material service practices can be improvements of existing processes or entirely new practices.

Second, our study identifies important context factors in terms of organizational goals that are associated with an S-D logic. Future research efforts should focus on the enabling and constraining factors in actualizing the service practices and how these practices should be implemented (cf. [47]). For example, further research could investigate certain service features to determine whether a service should be automated or provided as a human-material practice.

Third, our study supports recent work highlighting that understanding technology affordances requires analytic approaches that simultaneously consider, for example, aspects of materiality, humans, and context in light of organizational level goals.

Fourth, both the dynamic changes in material features of BDA and the organizational context offer opportunities for longitudinal studies that examine the development of BDA affordances and service-provision practices.

Implications for practice

Our findings have four primary implications for practitioners who design BDA infrastructures to support service innovation. They provide guidance for the design and implementation of technologies that deliver the material features for service automation and human-material service practices.

First, the development of BDA technologies is highly dynamic, and different instantiations of a technology might provide similar material features. Practitioners can use the categories of features identified in this study (sourcing and storage features, analytic features in terms of event recognition and prediction and behavior recognition and prediction, and exploitation features) to identify suitable and scalable technologies. At the same time, they can revisit their IT infrastructures to determine to what extent such features are present that might be exploited to afford service innovation or to determine whether they can be created through reprogramming. Future research could identify additional material features and associated affordances, thereby, informing BDA research about new material features that might be beneficial or even critical to additional service innovations, such as those in the area of security and privacy.

Second, practitioners can use the theoretical model to analyze their need for service automation or human-material service practices. As our analysis shows, some organizations balance automation and human-material service practices (as in the case of Companies A and B), while others focus only on human-material practices (as in the case of Company C) or automation (as in the case of Company

D). The appropriate strategy depends on the type of service as well as the customer's expectation. Our description of four cases provides some examples.

Third, the empirical insights from our case studies and our theorizing based on those cases provide fine-grained information about BDA's specific contribution to service innovation. Thereby, our results provide guidance to firms that seek to launch BDA-enabled service innovation. IT managers must have a holistic grasp on how BDA technologies afford different models of service provision such that the service provision is aligned with the organization's strategic goals. All four cases provide evidence that the companies' investments in BDA technologies and their application to service innovation was in response to specific action goals and that these goals had in common their focus on individualized service.

Fourth, the service innovations identified in this study might inspire the development of use cases for firms' specific use contexts and strategic goals.

Limitations

Despite the careful design of our research approach, our findings are subject to several limitations. First, qualitative research relies on the researchers' interpretation in coding and analyzing the data. While we applied established techniques suggested by Wallendorf and Belk [52] to ensure high-quality results, future research should repeat and refine our analysis. Second, as the use of information technologies is subject to subjective interpretations in specific contexts of use, it is unlikely that our account of the potential for service automation and human-material service practices is exhaustive. Future research could investigate whether additional uses emerge based on a comparable sample. Third, as our case organizations had a number of common characteristics with regard to ownership, business model, relevance of BDA to service innovation, and cultural proximity, our results may not be generalizable beyond this context. Future research might verify whether our results apply across contingency factors like other industries and other regulatory and cultural contexts. Fourth, although our firms have strong technological capabilities, there may be other firms, especially in the tech industry, that are pioneers in applying BDA. Future research could investigate whether these firms have put BDA to other uses, and in case of differences, shed light on why they occurred.

Conclusion

Our research lends support to the argument that BDA holds potential for service innovation [58] and identifies the factors that are pertinent to the creation of new value propositions. It identifies two key primary roles of BDA in the context of service innovation: (1) automation of customer-sensitive service provision, and (2) human-material customer-sensitive service practices, and highlights how these are grounded in material features of BDA. Together, these two types of service innovation allow organizations to revamp their value propositions.

Notes

1. The singular term "service" used here instead of the plural "services," emphasizes the focus on "service processes" instead of services in terms of "units of output" [24, 50].

2. Please note that we have adjusted our research question throughout this qualitative, exploratory study. However, the essence of our question in terms of the impact of BDA on service innovation remains the same as it was when we commenced the study.

3 While open coding is typically associated with grounded theory method, it is indeed used in exploratory, qualitative research in general [27, 43].

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Appendix

Interview Questions

A. Background

- What is your position within [case organization]?
- What projects do you typically/currently work on?
- What is your understanding of the term "big data"?
- Are you aware of big data initiatives at [case organization]?
- Do you have any tasks and responsibilities that are directly related to big data initiatives?
- What is your understanding of the term "big data analytics"?

To ensure a common understanding of big data analytics, we would like to introduce the following definition: Big data analytics refers to technologies for gathering, processing and analyzing big data, which commonly describes a vast amount of complex data.

- Based on this understanding, is [case organization] using big data analytics? And what role does it play at [case organization]?

B. Service innovation at [case organization]

In this interview, we aim to get an in-depth understanding of the role that BDA plays for service innovation at [case organization]. Therefore, we would like to ask a few questions about this topic.

- Do consumer-oriented services play a role in your organization? If yes, please describe them.
- What is your understanding of the term "service innovation"?
- Does service innovation play a role in your organization? If yes, please describe it.
- What do you think is the motivation of [case organization] with regard to service innovation?

C. The role of BDA for service innovation

- What role does BDA play for service innovation?
- What are the things you expect to be able to do with BDA in the context of service innovation?
- What do you think are the underlying goals of harnessing BDA for service innovation?
- Do you know about any BDA technology that is used at [case organization] for service innovation?

Let us now assume that your organization had all the necessary BDA technologies in place.

- What do you think could be the role of BDA for innovating or improving consumer-oriented services?

Subquestions, especially for interviewees with a technical background

- What does the current technological infrastructure for data collection and analysis look like at [case organization]? Please describe it in detail.
- By means of which technologies does [case organization] collect, analyze and apply big data? Or how does it plan to do this? Please describe the technologies in detail.

D. Conclusion

- Did we forget anything? Is there anything else you would like to discuss?
- Could we get back to you in case we have some (minor) further questions from our data analysis?