A Framework for Digital Business Processes

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***Abstract*—As society and businesses are changing due to digital transformation, traditional, analogue business processes need to be rethought and re-built. While information Systems research aims to support decision-makers in organizations with theoretically founded insights to support digitalization in practice, it sometimes lacks conceptual clarity, making it harder to apply its recommendations. This is especially true regarding terminology: There are no generally agreed-on definitions for central terms like "information" and "data", which would be helpful for organizations aiming to digitalize previously analog processes. This paper presents a framework covering digital processes in general. It shows how facts of the world are turned into digital data, then into information, which serves as the basis for decision-making. By defining digital data as digital representations of signs in the physical world and information as views of specific digital data, enriched by relevant context, it hopes to contribute to a clearer understanding of these terms. The framework is derived from an analysis of two sample processes, a) using a smartwatch to track movement and b) predictive maintenance in railway infrastructure using smartphones. It should be useful to research digitalization processes in other areas as well. Moreover, practitioners should find it helpful for discussions of digitalization projects.**

Keywords-framework; digital transformation; digitalization; data; information.

I. INTRODUCTION

Technological progress in areas like sensor technology, artificial intelligence or machine learning are driving digital transformation and creating opportunities to collect and analyze data at unprecedented scale [1]. As society and businesses are changing as well, digital transformation continues to be an area of the highest relevance as companies and organizations of all sizes are struggling to move their services and business models online, reconceptualizing what they do in the process. Moving business processes from the physical world (sometimes called the analog paradigm) to the digital world (the digital paradigm) may be challenging, but also offers an opportunity to rethink these business processes and the underlying business models, opening up potential for innovation along the way.

Existing research on digital transformation, however, often shows an astonishing lack of conceptual clarity: The key terms of "data" and "information" are not clearly defined, and definitions are sometimes contradictory or overlapping. This can be illustrated in the established research field of Information Systems (IS), which broadly looks at the interaction between organizations, information systems and the people using them [2].

Yet for a successful digital transformation to occur, it is important to have a clear conceptual framework outlining what happens in digitalization and, not least, unambiguous definitions of the main terms. As will be shown in Section II, there are currently no clear definitions of the terms “information” and “data” in research in the Information Systems field, which also limits our understanding of the processes involved in digitalization. Consequently, this paper will address the research questions: (1) “How can data and information be conceptualized, and (2) what happens to data and information in the process of digitalization?”

This conceptual paper presents a framework for digitalization, which was initially developed in a prior case study [1]. Section II will establish the theoretical background and discuss related works in the literature on IS and related fields. It outlines a framework conceptualizing the digitalization of business processes. Section III will briefly present the methodology of this paper. Findings will be presented in Section IV, which applies the framework to the case of predictive maintenance using smartphones in railway infrastructure. In Section V, the research questions are addressed and recommendations for practitioners planning digitalization projects are given. Section VI summarizes contributions to theory and practice and outlines possible future research directions.

II. THEORETICAL BACKGROUND

This section discusses fundamental terms. It follows Verhoef et al.’s [3] distinction between digitization, digitalization and digital transformation. Existing definitions of the terms “data” and “information” are then discussed and a framework is proposed to describe how facts of the world are turned into digital data, then into information, in the process of digitalization.

A. Digitalization, Digital Transformation

This paper draws on a broad theoretical background, mainly in the IS literature. For the key terms of digitalization and digital transformation, the definitions of Verhoef et al. [3] are used. They refer to three phases of digital transformation:

1. “Digitization is the encoding of analog information into a digital format (i.e., into zeros and ones) such

that computers can store, process, and transmit such information" (p. 891).

While essential, this purely technical process of encoding is not particularly exciting for organizations. The value of digital information (or data?), however, is seen in the following stages:

2. Digitalization "describes how IT or digital technologies can be used to alter existing business processes" (p. 891) and
3. Digital transformation is defined as "a change in how a firm employs digital technologies, to develop a new digital business model that helps to create and appropriate more value for the firm" (p. 889).

This helps to illustrate the relevance of digital transformation: "Digital transformation affects the whole company and its ways of doing business (…) and goes beyond digitalization – the changing of simple organizational processes and tasks" (p. 889). Thus, having digital data available is necessary to enable organizations to reconsider their business processes and business models. Both represent considerable opportunities to increase efficiency or identify new revenue streams [4].

B. Data, information

From these definitions, it becomes clear that data and information play a crucial role in digital transformation, as they constitute the key phenomena of relevance in digital systems. The first eminent publication on information was by Shannon [5], which is seen as the start of the field of information theory and has influenced fields from computer science to statistics and economics. However, as a communication engineer, Shannon was concerned with the efficient transmission of information, not with its meaning, so his theory does little to resolve the conceptual issues around digital transformation.

Unfortunately, the IS literature does not use the terms "data" and "information" with sufficient precision. McKinney and Yoos [6] show that, following the token view (the most common one according to their research), "information" is actually seen as synonymous with "data". Likewise, the definitions by Verhoef et al. [3] discussed above only refer to "information", not "data", hence a clearer distinction is needed.

Looking at the business management literature, there are more straightforward definitions. According to Laudon & Laudon [7], "data" are defined as "streams of raw facts" (p. 609) and "information" as "data that have been shaped into a form that is meaningful and useful to human beings" (p. 612). This is helpful for a clearer understanding: Data have something to do with raw facts, while information is primarily useful for human users. It also aligns well with the etymology of data as "that which is given". Previous attempts to equate data to facts of the world [8], however, have not been successful. To avoid confusion, this paper will refer to "digital data" throughout.

Starting from facts, in fact, should still be relevant to understand processes of digital transformation, as their purpose ultimately is to find out about events in the physical world, and potentially to affect them. Krcmar [9] discusses a hierarchical view of codes, data, information and knowledge: Syntax turns codes into data; context adds meaning to data, thus creating information. This is a useful view as it clearly distinguishes between the four different concepts.

Certainly, at this point, we can claim that there are enough differences between data and information to warrant using different terms.

C. A framework for digital business processes

Based on the literature discussed above, a general framework describing digital processes (e.g., business processes) was developed [1]. The framework describes how facts of the physical world are eventually converted into digital data, which is presented as information in order to influence decisions. For illustration purposes, the framework is used to discuss the simple everyday case of using a smartwatch to track a user's movements. The framework is shown in Figure 1. Specifically, the process runs as follows:

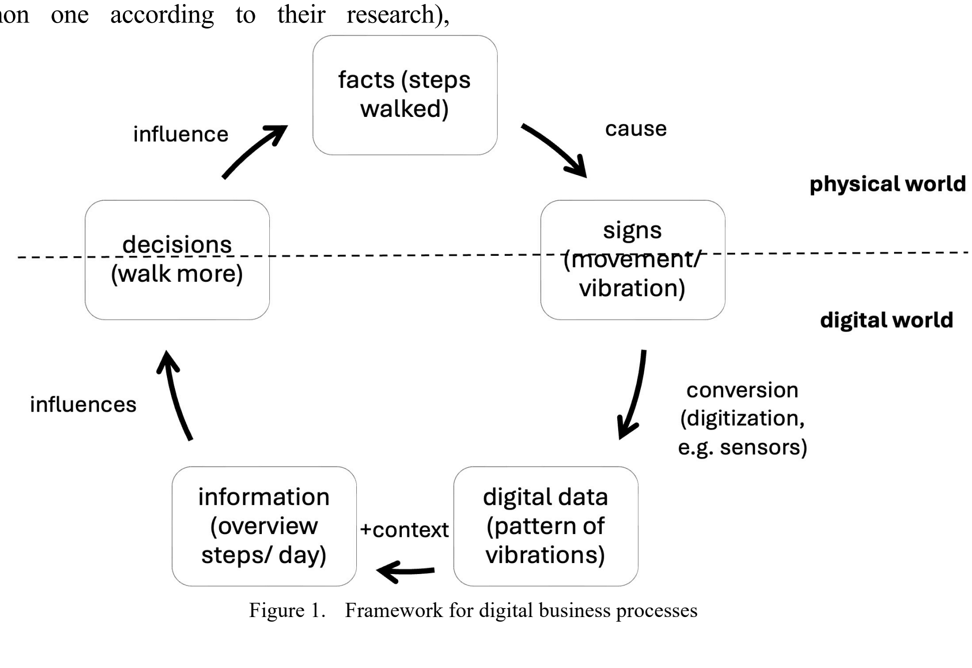

Figure 1. Framework for digital business processes

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- As mentioned, the framework shows how facts in the physical world are eventually turned into digital data (in the digital world). The dotted line represents the boundary between the physical and the digital world. Signs and decisions can both be located either in the digital or the physical world.
- The framework starts at the top, with the **facts of the world** relevant for the process in question. In this example, this is the number of steps taken by the person who wears the smartwatch.
- The **facts of the world** cause **signs** that can be measured – in this case, specific patterns of movement in the smartwatch. Signs can be either physical (as in this case) or digital (when looking at digital processes – see below).
- If necessary, the **signs** are then digitized. In this case, this is done by the motion sensor in the smartwatch, so the signs are turned into **digital data** corresponding to the specific pattern of vibrations that indicates a step has been taken.
- These raw **digital data** are not useful in themselves, but can be presented in a way that is, i.e., turned into **information**. This could be done by adding context to the data or by formatting them in a way that is meaningful to its users.
- In the end, the smartwatch will give a piece of **information**, e.g., the number of steps taken on this particular day, ideally compared to a target value that was defined before.
- This is presented in a way that supports **decision-making**. In this case, the user may decide to walk some more in order to reach their daily step target.
- Obviously, and crucially, this process also affects the original **facts** (number of steps), as the purpose of information systems is usually not just to measure effects in the real world, but also to change them.

The framework outlined will be discussed in the following sections, with a focus on how it can be applied to different contexts.

III. METHODOLOGY

The research design and methodology in this paper is relatively straightforward. The paper set out to answer the research questions: (1) “How can data and information be conceptualized, and (2) what happens to them in process of digitalization?”. This section will briefly outline how this is done.

The proposed framework is based on prior studies as well as a review of the literature on Digital Transformation. It is presented for the first time in English. The case study focuses on using smartphones for predictive maintenance in railway infrastructure. It is based on a case study in German [1], which analyzed the literature on the topic, discussing some previous research. The relevant key papers are listed in Table 1.

TABLE I. KEY PAPERS

Paper	Content	Findings
Nunez et al. [10]	Reporting on projects for cost effective maintenance in railways	Axle box acceleration measurements and smartphones both useful in coordination with other signals like GPS
Falamarzi et al. [11]	Review of various sensor technologies for inspecting railway infrastructure	Smartphones as cost-effective probe to collect acceleration data, gyroscope and GPS data, mostly for measuring ride comfort
Rodriguez et al. [12]	Review of earlier projects; methodology for measuring ride comfort	Possible to measure track performance and ride comfort using smartphones
Stübinger & Stavrianidis [13]	Reporting on a project by Siemens Mobility with Swiss Rail (SBB)	Project used smartphones to successfully measure some maintenance aspects, in conjunction with existing backend systems

The focus of the current, conceptual paper is on developing this framework and discussing ways it might be useful in other areas of research.

IV. CASE STUDY FINDINGS

A. Predictive Maintenance

The framework presented above can also be used to discuss cases of predictive maintenance, where collecting and analyzing facts about the world in the form of digital data is also a key aspect. Mobley [14] describes the basic approach:

“The common premise of predictive maintenance is that regular monitoring of the actual mechanical condition, operating efficiency, and other indicators of the operating condition of machine-trains and process systems will provide the data required to ensure the maximum interval between repairs and minimize the number and cost of unscheduled outages created by machine-train failures” (p. 4).

Consequently, transferring the framework to the realm of predictive maintenance shows it can be used to discuss processes of digitalization in this area as well. In this case,

- the starting point of the process is again **facts of the world**, i.e., the “actual mechanical condition” of a machine.
- These cause **signs** in the physical world, i.e., the “indicators of the operating condition”, e.g., movement or vibration.
- These are then converted into **digital data**, e.g., by sensors.
- These **digital data** (i.e., “the data required”) can be enriched with an appropriate context and used as **information** to support **decisions** (i.e., “ensure the maximum interval between repairs”).

- The **decisions** that are made in this way in turn affect the original **facts** (i.e., “minimize the number and cost of unscheduled outages created by machine-train failures”).

In predictive maintenance, it is not the facts of the world being digitized, but certain signs in the physical world indicating them. Specifically, it is not the mechanical condition of the railway track itself, but the measurable signs indicating this condition, e.g., slight variations in the movement or vibration patterns of the train. These are turned into digital data and, by contrasting this with previous data, a context is established that can yield information about the track’s condition (specifically whether it is damaged). This can inform decisions (e.g., adapting the maintenance intervals for the track), which again influence the initial facts (the track’s condition).

B. Example: Maintenance of railway infrastructure using smartphones

The capture of facts of the world and their processing as digital data for predictive maintenance can be illustrated by the case of railway operators using commercially available smartphones to detect damage to railway infrastructure [1]. To this end, there have been various experiments with apps that are installed on smartphones, which are positioned at various points on a train and continuously provide data on the condition of the tracks via, e.g., the smartphone's acceleration or gyro sensors. As such data can ideally be collected every time a train is running, changes over time can be identified and used to infer possible maintenance requirements.

Initial results are promising. Nunez et al. [10] and Rodriguez et al. [12] evaluate the previous use of various sensor technologies In railways, finding that smartphones are useful for some aspects of predictive maintenance. This is supported by Falamarzi et al.’s review of the literature on various technologies for the maintenance of railway lines [11]: “The combination of different sensors has made smartphones a cost-effective probe which can be used to collect acceleration data, gyroscope and GPS data in railway vehicles, mostly for measuring ride comfort” (p. 6). At the same time, the authors qualify that the use of these technologies is still in at an early stage.

Stübinger & Stavrianidis [13] present an app developed by Siemens Mobility, which supports the monitoring of rails in daily use. This is traditionally done with special track measuring trains, which, however, cannot be used on a daily basis. In this example, three smartphones were placed in a regular train for a day and collected data, which were also combined with other external data:

“The smartphone app enables the recording and use of all relevant data from the smartphone sensors (e.g., Global Navigation Satellite Systems sensor (GNSS), accelerometers and gyroscope) during regular train operation. The optimum use of a smartphone for detecting faults in the infrastructure also requires the combination of additional external and freely available information with the sensor data. For example, the track monitoring smartphone app uses the OpenStreetMap map material that is integrated through a special interface” (p. 10).

A traditional measuring train was used for comparison. The quality of the data was found to be similar: “Valid use of the data can be established based on the good qualitative comparability of the smartphone data with that of the accelerometers in the train vehicle body” (p. 12). The app is integrated into existing measurement and monitoring solutions for trains and rails [15]. Thus, the way the underlying system works is similar to the process shown in our framework: digital data is collected from sensors and external sources, processed and made available for analysis.

The case study has shown that protective maintenance is fundamentally about converting facts of the world into digital data and using this as information to support decision-making. Consequently, it can be described in the terms of the framework presented in this paper.

V. Discussion

A. Addressing the Research Questions

The framework has been introduced and discussed with reference to the two cases discussed, wearing a smartwatch as well as predictive maintenance in railway infrastructure using smartphones. This section will draw on these cases in order to address the research questions, then develop some recommendations for applying the framework in other contexts.

1) RQ1: How can data and information be conceptualized?

The problem discussed at the beginning of this paper was the lack of conceptual clarity around the terms “data” and “information”. Using the proposed framework, we can now propose alternative definitions:

Data, or specifically **digital data**, can be defined as digital representations of signs in the physical world, which in turn represent facts of the physical world. In our examples, the facts are the variables of interest in the physical word that are monitored and consequently modified. In order to do this, some measurable signs representing these facts need to be identified. If these signs are not digital, a way to digitize them has to be found.

Information, on the other hand, is defined as views of specific digital data, enriched by relevant context, that serve to support specific decisions either by humans or automated systems. The challenge is to identify the relevant digital data and any context necessary and to present them in a way that best supports the necessary decisions.

2) RQ2: What happens to data and information in the process of digitalization?

In the process of digitalization, relevant facts of the world are identified. Next, measurable signs relating to these facts are identified. These signs are then digitalized, i.e., converted into digital data if needed. The digital data is then enhanced with context and presented in a way that is useful for supporting decisions, i.e., it is turned into information. This information is then presented in a way that can support decisions, either by humans or automated systems.

It is worth pointing out that, as digital transformation progresses, such processes are becoming more pervasive. Specifically, the on-going digital transformation of many organizations makes it possible to obtain considerably more digital data, as more sensors and new data sources become available. This can be seen both in the fact that individuals carry more digital devices (and sensors) like smartphones or smartwatches, but also in automobiles, which have become digital devices in their own right in recent years [16]. Moreover, with technologies like noSQL databases and cloud computing, information can now be stored in almost any quantity and analyzed in real time.

B. *Recommendations*

The framework and associated definitions can thus support efforts at digitalization, especially around digitizing processes of supporting decisions based on facts of the world. This should be relevant for most business processes. Some specific recommendations for starting and designing such processes can be suggested.

1) *Identify relevant signs*

Obviously, information systems are always based on facts of the world. Being aware of this can help focus on facts and guide discussions about which facts are relevant for a specific business decision. The next step would then be to consider how these facts manifest in measurable signs that can be used for decision-making and, if necessary, think of ways to digitize them.

One example would be the number of customers in a specific timeframe, either in online or physical stores. In online stores, visitors leave information that can be tracked and analyzed, including how they arrived at the store website (e.g., from a search engine, a newsletter,…), how they navigate through the site, what purchases they made (if any), from which page (URL) they exited the store etc. Using the proposed framework, these would all be seen as signs in the digital world.

Similar signs exist for customers visiting physical stores in the real world. Here, data collected from cash desks can reveal insights about the number of customers throughout the day, revenues etc. If the store is using loyalty programs, these insights can also be tied to specific customers, revealing more insights about their behavior [17]. Some stores have come up with ways to analyze customer footfall while preserving privacy, e.g., by installing cameras to count customers entering the store, while only taking pictures of their feet [18].

2) *Consider UX and interaction design*

In order to be useful, digital data must be brought into a form that can support decisions. Thus, it must be presented in a way that supports these decisions and enhanced by any necessary context. This turns data into information.

For supporting the decision-making process, it is important to present exactly the right bits of information, and do this in a way that best supports decision-making. Insights from the field of User Experience research (UX) and interaction design [19] can be particularly helpful here. Thus, the next recommendation is to carefully think through the processes involved, the exact bits of information needed, and the best ways to present them. It can be especially relevant to consider external information that can be used in the process. As we have seen, the Siemens system for predictive maintenance in railway infrastructure [13] also uses geolocation data, weather data etc.

3) *Evaluate automatization options*

Once the useful signs, data and information have been identified, processes should be discussed with a view on automating them as far as possible. This can be illustrated by the case of using smartwatches for tracking activities: Some apps are able to automatically recognize typical signs (in this case, movement patterns, e.g., signaling that the user is running) and automatically trigger the desired reaction, e.g., recording the exercise activity, in this case the run, from the moment the pattern started.

Likewise, decisions should be automated, as, for example, is the norm in industrial production processes. Significant innovation can be expected in the area of business process automation in the near future as tools like Robotic Process Automation (RPA) or AI based tools like Microsoft Copilot are being used more broadly, and also in smaller organizations.

C. *Theoretical contributions*

The theoretical contributions of this paper consist in the definitions of digital data and information given above, as well as the framework for digitizing (business) processes, which should be useful for future research.

D. *Practical contributions*

The framework also represents an important practical contribution, as it is hoped that it will help practitioners plan projects of digitalization, identify useful facts of the world and ways they can be digitized.

VI. CONCLUSION AND FUTURE WORK

As small and large organizations everywhere continue to search for ways to digitally transform their existing business, a clear understanding of the processes involved is beneficial.

It is hoped that this research, and the framework presented, can contribute towards addressing the problems outlined at the beginning of this paper: The lack of clear definitions of the terms "information" and "data" as well as the limited understanding of the processes involved in digitalization caused by this ambiguity.

It is also hoped that the framework can support digitalization initiatives by putting a focus on relevant facts of the world and ways they can be digitized. Consequently, practitioners are especially encouraged to use the framework to structure discussions of digitalization projects.

This research, however, comes with clear limitations. The framework is still in an early stage of its development and will benefit from further testing on real-life examples. Future research should focus on critical discussions of the framework, as well as evaluating its explanatory powers in other areas of digitalization. It would be particularly helpful to have future case studies applying the framework in different contexts of digitalization.

References

[1] F. Allwein, "Wie kann die Digitale Transformation voraussagende Instandhaltung unterstützen?" [How can Digital Transformation support Predictive Maintenance?] in Predictive Maintenance: Innovationen, Anwendungen und Herausforderungen in der industriellen Praxis [Predictive Maintenance: Innovations, Applications and Challenges in Industrial Practice], M. Eifler, M. Nawito, and M. Venschott, Eds., Springer Gabler, 2025, in press.

[2] A. S. Lee, "Retrospect and prospect: Information Systems research in the last and next 25 years," Journal of Information Technology, vol. 25, no. 4, pp. 336–348, Dec. 2010, doi: 10.1057/jit.2010.24.

[3] P. C. Verhoef et al., "Digital transformation: A multidisciplinary reflection and research agenda," Journal of Business Research, vol. 122, pp. 889–901, Jan. 2021, doi: 10.1016/j.jbusres.2019.09.022.

[4] A. Osterwalder and Y. Pigneur, Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons, 2010.

[5] C. E. Shannon, "A Mathematical Theory of Communication," Bell System Technical Journal, vol. 27, no. 3, pp. 379–423, Jul. 1948, doi: 10.1002/j.1538-7305.1948.tb01338.x.

[6] E. H. McKinney and C. J. Yoos, "Information about information: a taxonomy of views," MIS Quarterly, vol. 34, no. 2, pp. 329–344, Jun. 2010.

[7] K. C. Laudon and J. P. Laudon, Management Information Systems: Managing the Digital Firm. Harlow, Essex: Pearson Education, 2014.

[8] F. Allwein, "Research Commentary: Data as Facts of the World," IS Channel, vol. 11, pp. 21–23, 2016.

[9] H. Krcmar, Informationsmanagement [Information Management]. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. doi: 10.1007/978-3-662-45863-1.

[10] A. Nunez et al., "Smart technology solutions for the NeTIRail-INFRA case study lines: Axle box acceleration and ultra-low cost smartphones," Proceedings of the 7th Transportation Research Arena 2018, 2018, Accessed: May 19, 2025. [Online]. Available: https://repository.tudelft.nl/islandora/object/uuid%3A501de6b4-38a4-43fd-9e92-dd82ee464748

[11] A. Falamarzi, S. Moridpour, and M. Nazem, "A Review on Existing Sensors and Devices for Inspecting Railway Infrastructure," jkukm, vol. 31, no. 1, pp. 1–10, Apr. 2019, doi: 10.17576/jkukm-2019-31(1)-01

[12] A. Rodriguez, R. Sañudo, M. Miranda, A. Gómez, and J. Benavente, "Smartphones and tablets applications in railways, ride comfort and track quality. Transition zones analysis," Measurement, vol. 182, p. 109644, Jun. 2021, doi: 10.1016/j.measurement.2021.109644.

[13] L. Stübinger and K. Stavrianidis, "Track monitoring smartphone app," ETR - Eisenbahntechnische Rundschau, pp. 10–13, Sep. 2022.

[14] R. K. Mobley, An Introduction to Predictive Maintenance. Elsevier, 2002.

[15] Siemens Mobility, "Measurement and monitoring for rail systems", Siemens Mobility Global. Accessed: May 19, 2025. [Online]. Available: https://www.mobility.siemens.com/global/en/portfolio/digital-solutions-software/digital-services/measurement-monitoring.html

[16] A. Lyyra, K. Koskinen, C. Sørensen, and T. Marion, "Tethered Architectures in Cyber-Physical System Development: The Case of Tesla's Autopilot System," Jul. 10, 2023, Rochester, NY: 4515061. doi: 10.2139/ssrn.4515061.

[17] C. Duhigg, Power of Habit: Why We Do What We Do in Life and Business, Random House Trade Paperback Edition. New York: Random House Trade Paperbacks, 2014.

[18] Affine, "In-Store Traffic Analytics: Retail Sensing with Intelligent Object Detection," Medium. Accessed: May 19, 2025. [Online]. Available: https://affine.medium.com/in-store-traffic-analytics-retail-sensing-with-intelligent-object-detection-51f7aea13a1a

[19] J. Preece, H. Sharp, and Y. Rogers, Interaction Design: Beyond Human-Computer Interaction. John Wiley & Sons, 2015.