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Ronny Baierl
Judith Behrens
Alexander Brem *Editors*

Digital Entrepreneurship

Interfaces Between Digital Technologies and Entrepreneurship

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Preface

Digitalization has been roiling markets and disrupting companies for more than two decades. It drives worldwide networking, innovation phases are being augmented through data operations, and the boundaries between industries are becoming distorted (Bughin and van Zeebroeck 2017). Digitalization is rapidly changing our living and working life. Robots are working together with people, autonomous systems are navigating us safely through traffic, and even the elderly can live a self-determined life with intelligent assistants. From an economic point of view, customized goods and services can now be offered at mass production prices. Despite all the hype, digitalization is not a new trend. The Third Industrial Revolution started as early as the beginning of the 1970s and has been continuing to this day. It is shaped by the use of electronics and information technologies in the economy as well as progressive standardization and automation of business processes. Digitalization is transforming the locus of entrepreneurial opportunities and entrepreneurial practices.

Even though different books and journal publications have already been researching digitalization activities (e.g., Nambisan 2017; Giones and Brem 2017), this book contributes to the current discussion by giving additional insights into the highly relevant area of digital entrepreneurship. Digital entrepreneurship is broadly defined as creating new ventures and transforming existing businesses by developing novel digital technologies or novel usage of such technologies. Digital entrepreneurship has been viewed as a critical pillar for economic growth, job creation, and innovation by many countries. Additionally, digital technologies have become a new economic and social force for reshaping traditional business models, strategies, structures, and processes. Digital technologies have enabled the growth of the sharing economy by linking owners and users and disrupting the previous dualism of businesses and customers. It is evident that digital technologies have a significant impact on the growth of entrepreneurs and their developmental processes. However, only a limited number of studies in entrepreneurship and technology research started to examine the impact of digital technologies on entrepreneurial decision making (e.g., Fischer and Reuber 2014) and on entrepreneurial activities for venture development (e.g., Allison et al. 2014).

Prompted by the significant growth of digital entrepreneurship and the lack of research in that field, this book studies the impact of digital technologies on entrepreneurial processes and outcomes in several contexts. The following chapters focus on the management of new technology-based firms as well as technology projects initiated in an academic or industrial context. The book is designed to assemble a rich, vibrant, and multifaceted collection of studies to enrich the discussion on and enhance the understanding of the reality and management of technology-based firms and projects. Thus, this book aims to be a standard reference in the field of digital entrepreneurship and to create a scientific basis for entrepreneurs, investors, universities, research organizations, and established corporations. As a result of our highly competitive review process, this book includes five chapters representing several perspectives of digital entrepreneurship. The following paragraphs summarize each chapter's main contributions based on the respective abstracts and introductions. The chapters are arranged alphabetically according to the first author's names.

The chapter entitled "Digital Entrepreneurship and Value Beyond: Why to Not Purely Play Online" written by Alina Arlott, Tassilo Henike, and Katharina Hölzle raises the question of why successful players that operate purely online turn to offline channels and what they can possibly gain from it. Furthermore, the topic of what digital entrepreneurs can learn from these experiences will also be addressed. The authors used four case studies including interviews and observations within the German health, consumer electronics, home furniture, and food industry to address these questions. They show that the addition of a physical offline presence adds value to these new ventures in a functional, emotional/social, economic, and status dimension. The interviewees confirmed that, sooner or later, many ventures must go offline. Only services that have a dominant online position have the chance to survive as pure online players.

The chapter entitled "The Role of Innovation and IP in AI-Based Business Models" written by Martin A. Bader and Christian Stummeyer gives insights into proprietary and open innovation approaches that are applied in artificial intelligence (AI)-based business models. Starting with the historical emergence of AI, the authors present the state of the art of innovation structures in AI applications and AI-based business models. Finally, they elaborate on the role of intellectual property (IP) with a special focus on patents by analyzing patenting data and the top AI patentees: corporations, research organizations, and top patenting AI start-ups. The authors conclude with their own model of formal and informal protection strategies applied in AI-based business models and how to balance open and proprietary innovation with a focus on entrepreneurship and start-ups.

The chapter entitled "Digital Absorptive Capacity in Blockchain Start-ups" written by Rosaura A. Chacón and André C. Presse targets different audiences such as entrepreneurs, researchers, CEOs, strategic managers, and business owners with necessary information about absorptive capacity (AC) and its relation to firm performance in the context of an increasingly digitalized economy. This topic is of special relevance since the acquisition of knowledge and its conversion into dynamic capabilities provide enterprises with the possibility to go through digital transition and transform the acquired knowledge into modified business models, innovative products, and upgraded services. Since the first crafting of AC theory, there has been ample research on its application in medium and large companies. The contribution of this study is that it assesses the concept of AC and its impact on firm performance in start-ups. The methodological approach involves quantitative data analysis using a survey applied to a sample of 44 blockchain start-ups. The authors analyze firm performance by applying different measures that were previously tested in other studies: sales growth, profit growth, growth in market share, and growth in return on capital. They find a positive relationship between AC and firm performance in blockchain start-ups.

The chapter entitled "Entrepreneurship in a New Digital Industry: The Emergence and Growth of Mobile Health" written by Lien Denoo and Helena Yli-Renko takes a deep dive into the mobile health industry and examines its origins, evolution, and structure. The authors discuss the unique features of mobile health as an example of a newly emerged digital industry and present a set of interdisciplinary research opportunities for scholars who are interested in digital entrepreneurship. Thus, this chapter contributes to our understanding of industry emergence, in particular the co-evolution of new ventures and a novel digital industry. Thus, the authors offer important insights for researchers, entrepreneurs, and policy makers.

The chapter entitled "Entrepreneurship as an Innovation Driver in an Industrial Ecosystem" written by Markus Hofmann and Ferran Giones considers the case of the leading players in the wind industry in Denmark in order to provide interesting insights on how entrepreneurs contribute to the introduction of new technology innovations in industrial ecosystems. The authors combine archival data and interviews with experts and actors in the industrial ecosystem to see if the characteristics of digital technologies facilitate the participation of new entrants. They also provide a review of the recent discussion on innovation and entrepreneurial ecosystems and a historical account of the wind industry ecosystems. Finally, the authors outline implications and takeaways for readers from the research and industrial area.

The chapter entitled "Virtual Reality as a Digital Learning Tool in Entrepreneurship: How Virtual Environments Help Entrepreneurs Give More Charismatic Investor Pitches" written by Oliver Niebuhr and Silke Tegtmeier deals with the entrepreneurial key element of the investor pitch. It examines if and to what extent the acoustic parameters of a charismatic tone of voice can be improved by rehearsing a pitch in a virtual presentation setting in comparison to a traditional setting in which speakers rehearse their pitch alone in a quiet room. For this purpose, speech-production and perception experiments are combined. About 5000 measurements were taken from the elicited investor pitches and the acoustic results were cross-validated by 31 listeners who judged excerpts of all pitches in terms of perceived speaker charisma. On this basis, the authors provide empirical evidence that the traditional rehearsal setting degrades the charismatic tone of voice of a speaker with each new repetition of the investor pitch. Rehearsing in a virtual reality environment, on the other hand, counteracts this erosion effect and even results in a gradual improvement of the speaker's charismatic tone of voice. Initial findings also indicate that this positive virtual reality effect persists when speakers return from the virtual to the traditional rehearsal setting.

The chapter entitled "Effects of Internal Corporate Venturing on the Transformation of Established Companies: Tackling the Digitalization Challenge" written by Christoph J. Selig, Tim Gasser, and Guido H. Baltes aims at answering how different corporate venturing forms contribute to the strategic renewal of established companies. For this purpose, qualitative research methods are used to analyze data from 17 interviews conducted in two German high-tech companies. This chapter provides empirical evidence in the field of corporate venturing by uncovering new insights about the different transformational effects of corporate venturing initiatives on the core organization. It further reveals that corporate venturing forms can be classified into two categories according to their respective level of entrepreneurship and frequency of execution. Both categories exhibit different transformational effects and can be considered complementary to each other.

The chapter entitled "The Internet of Things in a Business Context: Implications with Respect to Value Creation, Value Drivers, and Value Capturing" written by Victor Wolf, Jutta Stumpf-Wollersheim, and Lukas Schott focuses on the Internet of Things (IoT) as a network that connects devices and everyday objects to exchange data. IoT solutions consist of two elements, namely, the "thing" itself and its digital addition. Thus, these solutions deliver value, by including a physical "thing"-based function and a digital, connected IT-based function. Due to this hybrid nature of the IoT construct, firms have to rethink how to create and capture value. However, we still know very little about the influence of the IoT on value creation, value drivers, and value capturing in a business context. The authors conceptually analyze the potential impacts of the IoT on value creation, value drivers, and value capturing. With regard to value creation, they suggest that the characteristics of IoT solutions (the independence of the information stream and its accessibility) result in new possible ways of creating value and in specific drivers of value creation in IoT environments, namely, efficiency, network effects, customization, servitization and value co-creation, shared value drivers, and novelty. With regard to value capturing, the authors suggest that the hybrid value construct enables the value stream of digital information to be independently marketed, thereby allowing for completely new ways of capturing value in the IoT context.

This book is published as part of the FGF Studies in Small Business and Entrepreneurship. The book series serves as a vehicle to help academics, professionals, researchers, and policy makers working in the fields of small business and entrepreneurship to disseminate and obtain high-quality knowledge. We sincerely thank the editors-in-chief of the book series Jörn H. Block and Andreas Kuckertz for providing academic freedom in elaborating this editorial book's topic. Moreover, our sincere thanks go to the FGF as the leading and most important scientific association for entrepreneurship, innovation, and SMEs in the German-speaking world for supporting our intention to publish an editorial book in many ways. In addition, we are grateful for the highly professional services provided by Springer—namely by Ruth Milewski and Prashanth Mahagaonkar. Finally, we thank all authors of

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Digital Entrepreneurship and Value Beyond: Why to Not Purely Play Online

Alina Arlott, Tassilo Henike, and Katharina Hölzle

Abstract Digitalization has caused one of the most fundamental, behavioral shifts in human history and, in particular, how new as well as established companies operate in marketplaces. A large portion of the most valuable, worldwide companies nowadays concentrate on providing digital services without owning associated products or producing them. Yet, in a surprising change of strategy, an increasing number of these online pure players are now going into the opposite direction and open offline stores. This is surprising because these ventures are turning their disrupting success formula into the reverse. This raises the question why do successful online pure players turn to offline channels and what do they gain from it? Furthermore, what can (digital) entrepreneurs learn from these experiences? We used four case studies including interviews and observations within the German health, consumer electronics, home furniture, and food industry to answer these questions. In this chapter, we show that the addition of a physical, offline presence adds value for these new ventures in a functional, emotional/social, economic, and status dimension. The interviewees confirmed that, sooner or later, many ventures must go offline. Only services that have a dominant online position have the chance to survive as pure online players.

Keywords Digital entrepreneurship · Online pure players · Multi-channeling

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1 Introduction

Digitalization has caused one of the most fundamental, behavioral shifts in human history and, in particular, how new as well as established companies operate in marketplaces (Teece and Linden 2017). A large portion of the most valuable, worldwide companies nowadays concentrate on providing digital services without owning associated products or producing them. New digital ventures like eBay, Amazon, Facebook, Uber, Alibaba, Airbnb, or Netflix leveraged this massive shift from tangible products to intangible digital services and disrupted entire markets (van Alstyne et al. 2016). All these well-known companies are examples of online/ Internet pure players that started their business solely online without having physical stores for interactions (Dholakia et al. 2005; Xing and Grant 2006).

The rise of these online pure players documents a new form of digital entrepreneurship in that technology, i.e., the Internet, is an external factor and provides a platform for business interactions (Giones and Brem 2017). This platform comes along with varying advantages for companies, customers, and other involved actors in business interactions compared to earlier technology entrepreneurship. Lowered information costs with a simultaneous increase in information richness facilitate comparability and understanding of varying offerings for customers (Evans and Wurster 1997; Schoenbachler and Gordon 2002). It also facilitates companies' interactions with customers, value co-creation, and understanding of customers' needs (Demil et al. 2015; Nambisan and Baron 2009). Further, lowered resource requirements and market entry barriers allow new ventures to directly compete with incumbent companies (Autio et al. 2018).

Yet, in a surprising change of strategy, an increasing number of these online pure players—like Amazon, eBay, or PayPal—are now going into the opposite direction and open offline stores (Heinemann 2017). In Germany, digital ventures in various sectors like for mattresses (Emma 2017), glasses (Mister Spex 2017), food (MyMuesli 2017), or fashion (AboutYou 2015; Zalando 2018) are following this trend. This is surprising because these ventures are turning their disrupting success formula into the reverse. This raises the question why do successful online pure players turn to offline channels and what do they gain from it? Furthermore, what can (digital) entrepreneurs learn from these experiences?

Unarguably, competition in e-business is very attractive for varying ventures due to lower transaction costs and unlimited reach of customers (Sampler 1998). This potential raised much interest on how traditional brick-and-mortar companies can face digital transformation (e.g., Benner 2010; Kane et al. 2016; Nambisan et al. 2017). Yet, this attractiveness is sharply intensifying the competition and creates red oceans (Kim and Mauborgne 2005). Therefore, the coupling of digital businesses with physical stores could be considered as a strategy to escape these red oceans or to exploit new opportunities for growth (Reed and Luffman 1986). Yet, the motives why online pure players go offline are so far underexamined. Therefore, we use a series of case studies with well-known German online pure players and aim to understand their motives for opening physical, offline stores.

This chapter starts with a literature review to examine the changed conditions for entrepreneurs in the digital world. Second, we outline the effects of three general channeling strategies for entrepreneurs under these conditions: brick-and-mortar, click-and-mortar, and online pure playing. Third, through our case series within the health, consumer electronics, home furniture, and food industry, we add new insights that go beyond existing knowledge of why online pure players add physical stores to their online businesses.

2 Digital Entrepreneurship

The classic differentiation of entrepreneurship from other forms of organizing businesses largely built on differences: in the size of working teams, persons with unique attributes, the handling of risks and uncertainties, exploitation of niche opportunity spaces, constraint resource dispositions, as well as the distinct focus on creating future goods and services. Much attention was devoted to the entrepreneurial person/team as "individual differences (e.g., attitudes, predispositions, traits, skills and abilities, and cognitive differences) influence the development of entrepreneurial intentions, opportunity search and discovery, decision processes and subsequent actions" (Frese and Gielnik 2014; Shook et al. 2003, p. 383). Thus, a first premise for new successful ventures was that the founders' and teams' characteristics were the central locus of value creation.

Moreover, the opportunity space of new ventures traditionally focused on rather niche market segments (Bhide 1994; Shah and Tripsas 2007). This focus on niche market segments allowed them to compensate for limited resource dispositions and deterred incumbent companies due to lower economy of scale advantages (Audretsch 1991). Accordingly, a second premise for successful new ventures was to address very specific market segments.

Another focus of entrepreneurship research has been on understanding the nature and sources of uncertainty and the ways by which entrepreneurial actions unfold amidst such uncertainty (e.g., Alvarez and Barney 2005; Busenitz 1996). Uncertainty constitutes a fundamental, conceptual cornerstone in entrepreneurship. It inherently determines entrepreneurs' beliefs whether personal desires can be fulfilled. Further, uncertainty determines whether the entrepreneur has the means to feasibly enact an opportunity and whether the business idea attracts enough customers as well as investors (McMullen and Shepherd 2006). Therefore, formal business planning was a third premise to describe the current state and future of a business (Honig and Karlsson 2004), to reinforce commitment (Liao and Gartner 2006), to build legitimacy with financiers (Greene and Hopp 2017), and to reduce overall uncertainty (Delmar and Shane 2003).

Based on these central premises, the classical realm of entrepreneurship was separated from other fields and specifically concerned with answering the questions "(1) why, when, and how opportunities for the creation of goods and services come into existence; (2) why, when, and how some people and not others discover and exploit these opportunities; and (3) why, when, and how different modes of action are used to exploit entrepreneurial opportunities" (Shane and Venkataraman 2000, p. 218).

Digital entrepreneurship is now rewriting these premises (cf. Autio et al. 2018; Giones and Brem 2017; Nambisan 2017; Srinivasan and Venkatraman 2018). Digitalization has rendered entrepreneurial outcomes and processes less bounded (Nambisan 2017) and diminished the aforementioned differences. It was never easier for young ventures to address a broad customer base, find financial support, and grow with an exceptional speed than in the digital world (Kupp et al. 2017). Moreover, incumbent firms aim to partner with and to be more like young ventures by absorbing entrepreneurial culture, agile working mechanisms, or experiment on smaller scales (Kupp et al. 2017).

In the digital world, founders' and teams' characteristics are not the central locus of value creation anymore. Uber and Airbnb are prominent examples of digitally driven, entrepreneurial ventures, although they are orchestrating very traditional services like providing transportation or rooms for rent (Sussan and Acs 2017). Thus, the first rewritten premise is that not only specific persons create value, but that value creation happens among persons not employed by entrepreneurial firms. These digital entrepreneurs use the digital infrastructure to make value creation happen, but they are not the owners of this technological infrastructure. That distinguishes digital entrepreneurs from technology or digital technology entrepreneurs (Giones and Brem 2017).

Digitalization is also rewriting the second premise as new ventures are now able to attack incumbents that traditionally had a superior set of resources (Srinivasan and Venkatraman 2018). Due to lower communication and information costs, firms know much more about customers and can provide individual and on-demand solutions for customers (Christensen et al. 2018). Therefore, entrepreneurial ventures do not primarily address a specific group of customers anymore, but instead a dynamic, extensive collection of customers with varying goals, motives, and capabilities (Nambisan 2017; Sussan and Acs 2017).

Third, launching a new enterprise has traditionally involved writing a business plan and pitching it to investors (Blank 2013). Due to rapid possibilities for prototyping, several techniques have been proposed to not focus too much on a desired goal but to start lean by taking action and design them along the process (e.g., Baker and Nelson 2005; Sarasvathy 2001). Additionally, the rise of matchmaking platforms has lowered the need for business plans as financing possibilities have broadened from individual persons and institutions to the crowd (Schwienbacher and Larralde 2012).

These effects changed the classic nature of entrepreneurship that is summarized in Table 1. These changes are mainly based on advancements in digital technologies that manifest in three elements: *digital artifacts*, *digital infrastructure*, and *digital platforms* (Nambisan 2017). Artifacts are objects created by human interventions that, historically, had an enduring character with clear authorship and a physical nature like books (Allison et al. 2005). In contrast, *digital artifacts* are editable, interactive, and open and can be easily distributed (Kallinikos et al. 2013). These

Table 1 Shifts in the realm of digital entrepreneurship

	Classical entrepreneurship	Digital entrepreneurship
Entity	• Small, local ventures	• Rapidly growing international ventures
Locus of value creation	• Founder/founder team and personal attributes	• Value co-creation among diverse parties
Financing	• Institutions • Business Angels	• Crowd
Opportunity spaces	• Market niches • Superior degree of innovativeness	• Digital goods • Digital infrastructure • Digital platforms
Uncertainty handling	• Formally planned	• Lean/effectuating • "Fail fast, fail early"
Resource allocation	• Difficult	• Simple
Team allocation	• Personal peers	• Community of interest

Authors' own table

characteristics emphasize that *digital artifacts* are far more mutant than physical objects. Thus, digital artifacts offer new functional capabilities and value for archiving, searching, sharing, and collaborative working that provide new opportunities for creating value.

The access to these digital artifacts is controlled by second-order technologies (e.g., 3D printing, processors, servers, memory, operating system) that build the *digital infrastructure*. The digital infrastructure is the enabler to access and to distribute digital artifacts. The extensive efforts to rapidly expand digital infrastructure propelled globalization and the engagement of a greater number and diverse set of people in all stages of the entrepreneurial process—from finding collaborators to serving markets worldwide (Aldrich 2014).

While *digital infrastructure* enables one-to-one interactions, there is a third element of digitalization that today enables young ventures to reach a valuation in four years that Fortune 500 companies reach in an average of 20 years before the digital age (Morvan et al. 2016). *Digital platforms* are shared, digital architectures that enable many-to-many interactions between multiple groups or devices and enable a greater variety of offerings by variably combining standardized core modules (cf. Rochet and Tirole 2003). *Digital platforms* are built upon the *digital infrastructure* and cross-side network effects (Hagiu 2014). Accordingly, multiple parties benefit from the value created on digital platforms and the value on one side of a platform typically increases with the number of participants on another side—and vice versa. Platform-providing ventures do not necessarily create value themselves, yet they are responsible to orchestrate both value creation and value appropriation among the involved parties (Nambisan and Sawhney 2011). This potential to specialize in orchestration and to outsource costly value creation activities leads to a high attractiveness of digital platforms for new ventures (Zahra and Nambisan 2011).

All in all, these developments allow us to differentiate digitally driven ventures into two forms (Giones and Brem 2017). First, *digital technological ventures* concentrate on providing digital infrastructures. Second, *digital ventures* concentrate on producing digital artifacts or on providing digital platforms. Besides this focus on how digital ventures create value, digitalization also influences the interactions between actors involved in business interactions. This influence distinguishes brick-and-mortar businesses from click-and-mortar businesses as well as online pure players.

3 Brick-and-Mortar, Click-and-Mortar, and Online Pure Playing

Online pure players focus solely on operating their business online and derive all their revenue from e-business activities (Amit and Zott 2001; Wolfinbarger and Gilly 2001; Yoo and Lee 2011). These activities include services like providing digital artifacts or acting as a digital platform. Compared to the offline world, these digital platforms connect more efficiently and less costly varying parties (Dholakia et al. 2005). Additionally, costs for digital content reproduction are substantially lower. Thus, digital ventures can realize economies of scale easily and quickly due to the ease of information reproduction (Richter et al. 2017). These effects strongly pressure traditional firms operating in business-to-consumer segments like retailing, insurance, or consumer financial services (Grossman 2016).

Online pure players are distinct from brick-and-mortar companies as well as click-and-mortar companies (Steinfield et al. 2002). While brick-and-mortar companies do not operate online at all, click-and-mortar companies use a multichannel strategy by coupling online and offline stores. A look at the sales volume of the German retail industry reveals that online sales have increased in the past years and continue to increase. Yet, it is only responsible for 7.8% of the total sales volume (Heinemann 2015). There are multiple reasons behind that fact, such as slow and expensive shipping, the challenge of returning products, and the difficulty of inspecting non-digital products (Forman et al. 2009). Moreover, some customer groups enjoy the offline shopping experience, preselection of offerings, and personal contact in offline stores (Dholakia et al. 2005). This seems to be especially important for experience goods because only direct experience allows customers to fully understand essential product attributes (Chiang and Dholakia 2003). These physical experiences are critical for a long-term customer loyalty as attention is driven more toward the brand (Crockford et al. 2013) and as creating loyalty is a severe problem for online pure players (Ghazali et al. 2016).

However, a specific look at the German retail industry shows that soon nearly 50% of all non-food purchase decisions are prepared online (Heinemann 2015; Stojković et al. 2016). Additionally, the rise of digital ventures is propelled by reduced information search costs and limitless information availability that was historically a trade-off (Sampler 1998). In consequence, brick-and-mortar companies for search goods face considerable disadvantages compared to digital ventures (Chiang and Dholakia 2003). In the digital world, information reaches numerous target groups without losing the richness of the content and with significantly lower transaction costs (Lee 2001). Steinfield et al. (2002, p. 94) outlined the following advantages of digital ventures:

> [. . .] access to wider markets, lower inventory and building costs, flexibility in sourcing inputs, improved transaction automation and data-mining capabilities, ability to bypass intermediaries, lower menu costs enabling more rapid response to market changes, ease of bundling complementary products, ease of offering 24/7 access, and no limitation on depth of information provided to potential customers.

In general, digitally driven ventures are distinct from brick-and-mortar companies by the breakdown of time and location constraints. Therefore, increased convenience and greater time, effort, and price savings are major reasons for customers to interact online with providers (Chiang and Dholakia 2003). Yet, due to the nearly limitless, costless, and timeless reach of information, customers have a higher market power and can easily compare multiple offerings (Teece 2010). At the same time, due to lower operational costs, digital ventures can provide discounts on market prices resulting in the expectation that digital content is available for free (Richter et al. 2017). Firms also benefit from the extensive, digital footprints of customers and can collect an enormous variety and volume of customer information to better understand their expectations. Yet, Christensen et al. (2016) conclude that knowing more and more about customers does not take firms to adequately understand what the customer hopes to accomplish in a given circumstance. Data protection and copyright issues pose additional challenges to business owners (Fodor and Brem 2015).

To sum up, although digitalization fundamentally changes the way of doing business, each of the three channeling strategies involves positive and negative effects (Table 2). Therefore, young ventures must carefully weight these effects and may change the strategic direction if circumstances have changed or if the strategy does not unlock the full potential.

4 Method

Given the phenomenon that more and more online pure players are surprisingly turning their disrupting success formula into reverse, we aimed to understand the circumstances and the online pure players' motives to open physical stores. We used a qualitative multiple-case study approach, primarily based on semi-structured interviews (Eisenhardt 1989; Yin 2013). A case study approach seems appropriate as it allows the study of personal, actual renditions and the deduction of general explanations (Yin 1981). A multiple-case study approach was chosen to improve the generalizability across different industries as well as ventures and to allow cross-case analysis (Yin 2013). In this way, the results inform about the existence of a singular

Table 2 Comparison of brick-and-mortar, click-and-mortar, and online pure playing strategy

		Types		
		Brick-and-mortar	Click-and-mortar	Online pure playing
Tasks	Information	Physical	Physical/digital	Digital
	Sales	Physical	Physical/digital	Digital
	Aftersales	Physical	Physical/digital	Digital
Portfolio	Products/services	Physical	Physical/digital	Physical/digital
	Interaction	Direct	Direct	Direct/versatile
Effects	Range of offerings	Low	Medium	High
	Global reach	Low	Medium	High
	Possibilities for information	Low	Medium	High
	Return expenses (for physical products)	Low	Medium	High
	Price levels	High	Medium	Low
	Operating expenses	High	Medium	Low
	Initial trust/loyalty	High	Medium	Low

Authors' own table

occasion or generic circumstances. Cases were selected according to their suitability and based on five criteria: (1) venture started as a pure online player; (2) venture currently possesses an offline store; (3) offline store is located in/near to Berlin to allow personal observation; (4) interview participants have responsibility for store or whole venture; and (5) ventures do not operate in the same industry. In preparing the interviews, these criteria were checked in a first phone call, via email, on the company's websites, and by visiting the stores.

We generated a list of ventures that started as online pure players and, later, opened an offline store in Berlin. We then visited these stores and asked for interview partners according to our criteria. Appointments in person and on the phone were scheduled. In sum, interviews were conducted with founders and regional managers in the health (HealthVen), consumer electronics (ElectronicsVen), home furniture (FurnitureVen), and food sector (FoodVen). Conducting interviews with executives from different industries allowed us to examine whether the motives are rather industry-specific or generic.

For generating data and for ensuring data triangulation, we used three different sources: observations of the online facilities, observations of the offline stores, and interviews. The visits of both kinds of facilities were recorded with the help of observation protocols and enabled the detection of specific differences. During the interviews, interviewees were first asked to give some information about their position and background. Afterward, semi-structured interviews were carried out based on interview guideline. The guideline was created based on Reed's and

Table 3 Overview and relevant case information

Venture (Position of interviewee)	Number of stores in 2017	Business portfolio	First store opened in. . .
FoodVen (Co-founder)	50 (Germany)	B2C Digital service Physical product	2007
ElectronicsVen (Regional Manager)	14 (Germany) 2 (Austria)	B2C/B2B Digital platform Physical products	2005
HealthVen (Co-founder)	1 (Germany)	B2C Digital platform Physical products	2016
FurnitureVen (Showroom Manager)	6 (Germany) 1 (Austria)	B2C Digital platform Physical products	2016

Authors' own table

Luffman's diversification motive model (Reed and Luffman 1986) and reviewed during the collection phase. Interviews were tape-recorded and fully transcribed to achieve consensus, accuracy, and completeness. Yet, due to accessibility constraints, a few interviews had to be conducted on the phone. Interviews took between 30 and 60 min. For securing high anonymity, all interviews were fully made anonymous and we use acronyms for all ventures (Miles and Huberman 1994). Table 3 gives an overview of the cases.

After collecting data, the three researchers independently analyzed the data. First, cases were separately analyzed based on their characteristics. Then, the analyzed transcripts were compared in a cross-case analysis (Eisenhardt 1989; Miles and Huberman 1994; Yin 2013). The analysis focused on the explanations why purely online players open physical stores. It turned out that the explanations focused on different benefits for the customers, for the ventures, and for their partners. Consequently, we decided to structure the analysis according to Sweeney's and Soutar's framework (Sweeney and Soutar 2001) for analyzing value according to four dimensions: functional, emotional/social, economic, and status value.

5 Motives to Not Purely Play Online

Based on the comparison of the three strategic alternatives, online pure playing offers several advantages compared with brick-and-mortar or click-and-mortar strategies. In the situation where ventures decide to open physical stores, advantages like lower operating expenses and lower prices diminish. Nonetheless, in three of our four cases, the opening of a physical store was a conscious decision and a necessary endeavor. Only in one case, the opening of an offline store was a coincidence and the store was originally hired for another purpose. Yet, at the current moment, it turned out that this coincidence was a right decision and more store openings followed afterwards. To display systematically why opening physical stores was of value for these ventures, we organize our analysis according to four value dimensions (Sweeney and Soutar 2001): functional, emotional/social, status, and economical.

> In the end, I think for [ElectronicsVen] it was a logical consequence to open a store, although it relates to a lot of risk, because traditional retail is very expensive compared to online. It was also not easy to add the offline channel, as we did not know a lot about this business yet. For example, our procurement employees still have difficulties to think stationary. The planning of the product range is still difficult. [Manager, ElectronicsVen]

5.1 Functional Dimension

Entering the online facilities in our cases, three of our four cases show a similar, classical structure. The first page presents exemplary products in the ventures' colors and at the top of the page the user can navigate to the various offerings. Moreover, the three cases show directly on the first page where the next offline store can be found. Only HealthVen follows a different, reduced structure that directly informs about its service and that does not show directly the location of its offline store. In every case, the user has to navigate to the page of interest. Entering the physical facilities, all ventures follow a similar room design. They use light-filled rooms with high ceilings, and different areas of the physical stores are highlighted by assorted colors. Due to the limited space, all ventures only present their bestsellers within their stores. Thus, the customer is guided through the location and does not have to navigate on his own. This guidance enables customers to detect offerings that did not stand out to them online. Additionally, the main products are accompanied by other products that could be useful complementarities and that enhance customers' imagination. This kind of presentation differs from the online presentation in that each product is presented in isolation. Thus, the offline presentation generates an added value for the customer by displaying the whole picture and by stimulating the decisions to also order complements to the initial product.

> That way we can offer the combination of different products and always add small details and features. We can thereby generate an added value for the order, when the customer really likes the lamp or coffee table. It is a different kind of inspiration. [Manager, FurnitureVen]

The offline store also enables customers to pick up products directly. One of our interviewees mentioned that this is especially important for their business customers. Electricians, craftsmen, and PC specialists have their own customers that expect immediate services so that these businesses need quick solutions and cannot wait for online deliveries. Therefore, the offline stores address the needs in the B2B segment. Yet, also non-business customers appreciate the possibility to pick up their products directly.

> Well, in the ideal case, you open a new channel to generate additional revenue or to win more customers. Or, on the other side, we at [FoodVen] think very product driven and customer driven, so to enable our customers an easier way to get our products and try out products. [Founder, FoodVen]

The offline stores use this direct customer contact not only for quicker deliveries but to introduce new campaigns, to test new products, or to host extraordinary events. These activities in the offline stores generate directly additional value for the companies as well. The ventures learn what the customers want, how the customer reacts when addressed, and how assistance is showing effect on the customer. In this way, HealthVen discovered the right point in time when to approach the customer with their products. In the stores of FoodVen, their products are combined with other ingredients so that fresh food and healthy drinks are offered every day. This offering enables customers to try their products before the purchase and give direct feedback to new products. Therefore, the ventures stress the importance of the offline stores for experimentation and learning.

> The store exists since May 2016 with two main goals. First of all, for us to be able to review our own work, as we do not work together with our partner providers throughout the customer journey. Second, to build a test laboratory where we can test new campaigns on the customer. [Founder, HealthVen]

The learning aspect is a central aspect for all ventures. In their online facilities, they cannot directly perceive what effects specific functionalities have on the customer, where customers stop their journey, or what disturbs them. Via the direct interaction in stores, the ventures notice these critical points by observations, talks, and their experiments. All our interviewees agreed that it is central for the online as well as offline store to constantly adapt to customers' needs and improve the features provided. Both facilities, online and offline, directly interact with another and the data generated is used to improve for instance the cashier system or to decide what products need to be presented in the offline stores based on the online demand.

> We discovered what our real no-show rate is and were able to steer against that. [Founder, HealthVen]

The final functions of the offline stores relate to the ventures' partners. For HealthVen that operates as a digital platform, the offline store offers the possibility to invite partners, to provide trainings, and to create knowledge exchanges. Besides collaborative advantages, ElectronicsVen mentioned that they were obliged to present partner products online to be allowed to present these products online as well.

> Some manufacturers require an offline store in order to be allowed to also sell the products online. Also, for B2B customers, it is important to be able to pick up the products in a physical store. [Manager, ElectronicsVen]

In sum, the offline stores offer direct functional advantages compared to the online facilities for customers, for the ventures, as well as for the ventures' partners. In this sense, the offline stores function as test laboratories, quick pick-up stores, showrooms for complementary products, and partner meeting points.

5.2 Emotional and Social Dimension

Besides the functional aspects of opening an offline store, all ventures stressed the fact that, in the digital age, it is challenging to appeal to customers emotionally. Therefore, the stores are designed to create a specific touch and feel, familiar atmosphere. Feelings are transported by the lights, the systematic arrangements of the products, and music. All our cases are rather experience than search goods and, thus, the ventures try to generate an additional value for customers in addressing customers' experiences. The presentation of whole solutions packages appeals to customers' imagination and creates a certain kind of belonging to the ventures and their products.

> The more we are able to address the customer directly with the product, the higher the chance that the customer will buy. Online, we have zero emotional attributes, although offline you are influenced by the surrounding, the music in the store, the sales persons, the atmosphere in the room, which I think is a huge advantage. [Manager, ElectronicsVen]

This belonging is foremost propelled by the way of interaction in the stores. The employees are a crucial factor in that they consult and show alternatives or complementarities. The possibility to touch products is another way belonging is created. This possibility transforms the online object into a commodity. Customers can see how the products fit into their life. FoodVen uses small information cards to show specific characteristics and ingredients of their products and stresses the healthy aspects of their products combined with the provision of fresh fruits and vegetables. The ventures tried to transport these emotional aspects into the online world, yet noticed that the offline, emotional effects were not created equally. Thus, the offline stores function as a guarantee of the products' quality and services' trustworthiness.

> Most customers still prefer to actually talk to someone face-to-face, or like to touch, and feel the product first. [Manager, ElectronicsVen]

> We have always offered something like this, which was a 30-day trial period, however, the customers have had difficulties with this and did not want to have this effort for themselves. They want to be sure that whatever they order, they are going to keep it. [Manager, FurnitureVen]

All interviewees agreed that creating trustworthiness was one of their main motives for opening the offline stores. Trustworthiness can also be created in online facilities, yet the effort needed is considerably higher than in offline stores.

ElectronicsVen explicitly mentioned the importance of dominant online players like Amazon. Ventures that are not listed in Amazon are outcompeted. The same effect is related to Google and the presence in its ranking system. Ventures appearing in the top of these lists are regarded as more trustworthy than ventures in rear positions. Nowadays, trustworthiness is largely associated with the ease of finding a venture in the lists of dominant players. As more and more ventures open online facilities, the competition for the top seeds is getting more expensive. Therefore, opening an offline store is a possibility to show the seriousness and long-term perspective of a venture. Customers gain the feeling to have a personal touchpoint for problems in the future and include this long-time perspective into their decisions.

> Background for opening the stores was that we wanted to strengthen the brand, we wanted to gain trust in the brand. [Manager, ElectronicsVen]

> The online competition is getting tougher, and not every online store is linked with Amazon, which makes the customer wonder, whether it is trustworthy to order. [Manager, ElectronicsVen]

5.3 Economical Dimension

> Absolutely, the store has to be profitable. We are not doing this for fun. [Founder, HealthVen]

All interviewees agreed that their offline stores are neither only add-ons to their online facilities, nor should they only create a familiar atmosphere. All stores have also an economical value for the ventures. However, profitability is a matter of concern for the ventures as no cross-subsidization takes place and as operating costs as well as product prices are higher in the offline stores. The manager from ElectronicsVen explicitly mentioned that the stores are not profitable and that this is now their biggest challenge. Specific problems are the availability of products and price differences. If customers enter the store, they quickly notice a price difference between online and offline prices. ElectronicsVen actively communicates this difference to customers by digital price tags and explains the difference by the higher fixed and personal costs. However, most of their customers are already well informed and only pay the offline price for immediate product availability and for the service.

> A big point is the design of the prices. We have experimented a lot. It was difficult to communicate to our customers, they are getting a very good consultation, they are able to take the product with them immediately, and for that you might have to pay 2 percent more. [Manager, ElectronicsVen]

To economically profit from this situation, ElectronicsVen has to immediately provide the products requested and direct interest to other complementary products. Due to the price differences, the stores only become profitable when customers do not solely buy one product but a whole solution package. We already examined the functional aspect of complementary products for the customer, yet it becomes evident that they are not only add-ons, but necessary requirements for making offline stores profitable.

> We do not want to sell one product, but rather a whole solution. A business man needs a new laptop (. . .). The solution does not end there, the business man will need a case, a mouse, software, etc. These are the products which earn us money. [Manager, ElectronicsVen]

Although the economic situation is challenging for offline stores, the opening of offline stores has positive impacts on the whole venture. FurnitureVen and ElectronicsVen commented that one-third of customers entering their stores have not heard about the online facility. In these cases, the offline stores are the first touchpoints for the customers and expand the customer base. This is surprising as the online facilities promise to reach the broadest base of customers at any point and at any place.

> Whenever we are at a new location, customers did not know us before and only got to know us through the offline store. [Manager, ElectronicsVen]

The clue to explain this surprising result is the increasing fierce competition in the web. For ventures, it can be a rewarding strategy to shift marketing from online to offline. Based on Eisenbrand's analysis (Eisenbrand 2016), monthly costs to run an offline fashion facility in the center of Hamburg accumulate to 13,000 €. For the same amount of money, a venture can generate 13,000 clicks via Google AdWords and 390 sales. Thus, an offline store needs two sales per hour to reach the same amount of sales. Moreover, the purchase of additional complementary products leads to higher returns per person. Thus, the higher prices in offline stores can be compensated. Another side effect is that the costs for returning goods are lower.

5.4 Status Dimension

To stand out of the fierce online competition is a very strong motive in all our B2C case studies. All ventures link their offline stores to the effort to create a strong brand acknowledgement. That means that the venture name is known to the target group. Emotional relationships are mainly created by top positions in the systems of the dominant digital players. Moreover, the top positions have also a symbolic function and show that a venture's solution seems to be the most appropriate for customers' needs. Especially if ventures are unknown to customers and customers approach a venture for the first time, a venture's position is a strong motive for customers to enter an online facility. Thus, ventures lacking a dominant position must think about ways to create visibility.

> But we think that overall it developed positively, as the availability increased, as we gained more potential customers, and because the high availability and visibility also had a marketing effect. [Founder, FoodVen]

In our case studies, we had three digital platforms that were all specifically concerned on how their brand is connected to the physical products they offer and to what role they play in the value chain. We mentioned in the beginning that these ventures purposefully decided to open offline stores. The opening of offline stores directs attention away from the actual providers of the products to the distributors. Our interviewees mentioned that the customers mainly talk about the products and not their ventures. This negligence creates problems to attract new customers and confuses the actual customers as they do not know when to approach what party along the value creation process. Therefore, the offline store offers a way to better explain the function of the digital platform venture.

> Everyone is looking forward to the new opening in Frankfort, as it will get much more traffic than before, and people will recognize the brand more. [Manager, FurnitureVen]

> To be able to see in the store, where do we stand, (. . .), does he/she perceive us as [HealthVen] or is he/she unsure of how the two businesses are working together. [Founder, HealthVen]

Table 4 summarizes the results from our interviews and observations in the physical stores as well as webpages. These results cover many aspects from the effects described in Table 2. Yet, they express more fully that the addition of a physical store to a former pure online player is not only a blended form. Rather, it is a complement that allows us to attract new customer groups, to experiment, to sell solution packages, and foremost to explain the digital venture itself as well as to communicate trustworthiness beyond rankings on the Internet.

6 The Future of Online Pure Playing

> The strategy to go offline is not supposed to be a motive of growth. [Founder, HealthVen]

Our analysis shows that the diversification of online pure players into the offline business is not primarily driven by the motive to grow. All interviewees agreed that their strategic focus is still the online facility and that the offline stores only support the strategic focus. They treat the offline stores as necessary complements to run their online business. The number and location of offline stores are purposefully planned. All ventures plan to open new stores or adjust the existing ones without significantly expanding the number of stores. With reference to Reed's and Luffman's needs for diversification (Reed and Luffman 1986), online pure players mainly diversify into offline channels because they expect synergies. As ventures across different industry backgrounds were asked, the results also show that the motives for diversifying are similar across industries and relate to generic circumstances.

The interviewees expressed that their online facilities were not sufficient due to pressure from competition in the digital world. Running businesses solely online has significant advantages, yet only a minority is fully benefiting from these advantages. The fierce online competition leads to a confusing wealth of providers, and the trustworthiness of these providers is mainly judged by their rankings on dominant players' platform. Trust is of paramount importance for digital ventures, as many

Table 4 Summary of results

<table>
<tr><th>Value dimension</th><th>Characteristics</th><th>Effects of physical store addition</th></tr>
<tr><td colspan="3">Functional</td></tr>
<tr><td>Online</td><td>• First page presents exemplary products
• Information about various offerings
• Information about next store's location</td><td rowspan="2">For customers
• Easier exploration of products
• Increase in imagination
• Exploration of complementary products
• Quicker delivery of products (for B2B customers)
For venture
• Enhanced experimentation and learning
• Trainings and knowledge exchanges with partners</td></tr>
<tr><td>Offline</td><td>• Light-filled rooms, bestseller presentation
• Room design navigates visitors
• Presentation focus on package of products
• Used for product tests or for special events
• Some ventures are forced by partners to present products in physical stores as well</td></tr>
<tr><td colspan="3">Emotional/social</td></tr>
<tr><td>Online</td><td>• Rather low emotional engagement
• Need to be ranked outstandingly in Amazon or Google</td><td rowspan="2">For customers
• Closer affinity to products
• Guarantee for products' quality and trustworthiness
For venture
• Communicate a long-term relationship
• Physical touchpoint</td></tr>
<tr><td>Offline</td><td>• Specific touch and feel, familiar atmosphere (light, music)
• Employees consult and demonstrate products</td></tr>
<tr><td colspan="3">Economical</td></tr>
<tr><td>Online</td><td>• Lower prices and broader product range</td><td rowspan="2">For customers
• Lower availability of products
• Price differences confuse customers
For venture
• Need to communicate price differences and to sell solution packages
• Possibility to sell complementary products
• Attract new customers
• Lower costs for returns and marketing</td></tr>
<tr><td>Offline</td><td>• No cross-subsidization, profit interest
• Higher operating costs and product prices
• Customers need to buy solution packages</td></tr>
<tr><td colspan="3">Status</td></tr>
<tr><td>Online</td><td>• Better position in rankings, solutions seem to be more appropriate</td><td rowspan="2">For venture
• Create strong brand acknowledgement
• Convey role of the venture</td></tr>
<tr><td>Offline</td><td>• Direct attention from solutions to ventures</td></tr>
</table>

Authors' own table

customers question the liability of ventures regarding payment, shipping, and disclosure of personal information if they are not well known.

Research shows that consumers perceive less risk if ventures have an offline location where they can return products or talk to sales personnel (Steinfield et al. 2002). The lower the perceived risk, the higher the acceptance and online purchase intention. To have a customer's trust in the brand can also result in customer loyalty that leads to higher chances of repurchasing the same brand, positive word of mouth, and higher willingness to pay a premium price (Kwon and Lennon 2009). Our case ventures specifically looked for improving processes, communication, and overall procedures by interacting with customers offline. Based on these developments, our interviewees confirmed that sooner or later many ventures must go offline if they only ran online facilities before. Only services that concentrate on facilitating transactions or have a dominant online position will have the chance to survive as pure online players.

> I think it depends on the products. The products that we have, you will always find them solely online and offline, however, I think it brings huge advantages if the channels are connected and, in the long run, companies have to go offline sooner or later if they had been only online before. [Manager, ElectronicsVen]

> I think it depends on how deep the understanding of the customer has to be, in order to be successful. Simple transactional things like booking a flight etc., you do not really need it. With more complex services, you need more understanding of the customer. There will always be pure online shops. There will be more multi-channels for sure. [Founder, HealthVen]

The deeper the understanding of the customer and their (hidden) needs has to be, the more supportive an offline store can be. Simple things—like booking a flight—are easy and convenient for the customer online, without the need for the company to add an offline channel. Therefore, we propose that entrepreneurs must evaluate the need for going offline in terms of the value added to four dimensions: functional, emotional/social, economic, and status value. The following questions help to define the need for offline stores and to adequately mix online facility as well as offline stores:

- How much coupling with complementary products/services is needed?
- How much direct experience of the products'/services' functionality for both venture and customer is needed?
- How much explanation of the ventures' role in the value creation network is needed?
- How strong is the position in the dominant digital ecosystem?

These recommendations are based on our analysis of four German online pure players that mainly act as brokers between customers and providers. This specific focus limits the generalizability of our results. It may be that the explored effects are perceived differently by customers. Therefore, future studies should observe more closely the online and offline behavior of customers. Further, this study focuses on digital entrepreneurs that act upon physical products. In case of digital artifacts, the solution of adding physical stores may not have the same effects.

7 Conclusion

Undoubtedly, more and more businesses will be conducted virtually. In the sphere of search goods and services, there are significant advantages for online ventures compared to offline stores that will lead to a considerable decrease of travel centers, insurance offices, or other service offices. Although similar effects can be achieved for experience goods and services, the severe competition among online ventures will pressure the majority's viability. The opening of offline presences is neither only an add-on to online facilities nor driven by a pure growth motive; it is a strategic necessity if the position in the online sphere is threatened by huge competition. While the Internet likewise reduced information costs and enhanced information availability, the growing number of information puts severe challenges on trustworthiness and the ability to outstand from other competitors. Therefore, digital ventures must examine what functional, emotional/social, economic, and status value is added by offline stores in these regards.

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The Role of Innovation and IP in AI-Based Business Models

Martin A. Bader and Christian Stummeyer

Abstract We give insights into proprietary and open innovation approaches that are applied in artificial intelligence (AI)-based business models. Starting with the historical emergence of AI, we present the state of the art of innovation structures in AI applications and AI-based business models. Finally, we elaborate on the role of intellectual property (IP) with a special focus on patents, analyzing patenting data, and the top AI patentees: corporations, research organizations, and top patenting AI start-ups. We conclude with our own model of formal and informal protection strategies applied in AI-based business models and how to balance open and proprietary innovation with a focus on entrepreneurship and start-ups.

Keywords Artificial intelligence · Business models · Innovation management · Intellectual property · Patents · Open innovation · Proprietary innovation · Bought control model · Free public commons model · Startups · Entrepreneurship

List of Abbreviations

AI	Artificial Intelligence
CII	Computer-Implemented Inventions
EPC	European Patent Convention
EPO	European Patent Office

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GDPR	General Data Protection Regulation
IP	Intellectual Property
USPTO	United States Patent and Trademark Office

1 A Short History of Artificial Intelligence (AI)

1.1 The First Phase of AI: The 1950s

A test developed by Alan Turing in 1950 marks the first timestamp in the history of newer AI. The Turing test evaluates a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human. During the test, a human evaluator had to judge a natural language conversation between a human and a machine. If the evaluator cannot reliably distinguish the machine from the human, the machine is said to have passed the Turing test.

This test was at first only a theoretical sketch. If the history of artificial intelligence is considered academically, the "Summer Research Project on Artificial Intelligence," which took place in 1956 at Dartmouth College in Hanover, New Hampshire, is regarded as the birth of artificial intelligence. John McCarthy, the inventor of the programming language LISP, had organized a 6-week conference, which would later be referred to as the "Dartmouth Conference." Besides McCarthy, the AI researcher Marvin Minsky, the systems theorist Claude Shannon, the psychologist Alan Newell, and in economics Herbert Simon (who would go on to win a Nobel Prize) took part in this conference (Buxmann and Schmidt 2019).

All participants believed that intelligence could also be created outside the human brain. Also, they were inspired by Turing's earlier question, "Can machines think?" Therefore, the group investigated the cognitive processes of human problem solving and decision making and attempted to develop systems to simulate this human way of thinking.

Following this conference, AI research received a lot of impetus as computers became faster and cheaper and the capacity to store data increased. Progress has also been made in the field of artificial neuronal networks. An example here is ELIZA, a program developed by Joseph Weizenbaum, which was supposed to show the possibilities of communication between a human being and a computer via human language. This makes ELIZA itself the forerunner of the Chatbots that we see today—and already then it showed the enormous potential of AI. This first phase of AI research around the middle of the 1950s to mid of the 1960s was characterized by euphoric expectations (Buxmann and Schmidt 2019).

1.2 The Second Phase of AI: The Middle of the 1960s to the Middle of 1970s

The expectations in AI were high. However, the successes were low, as the computational power was insufficient. Thus, the period between the middle of the 1960s until the middle of the 1970s became known as the "AI winter" (Buxmann and Schmidt 2019).

Projects in that period had a greater focus on practical and specialized programming. First, specialized "Expert Systems" were developed, based on methods for knowledge representation, as well as systems to interact with through natural language (Mainzer 2019).

Around 1970, Winograd presented a robotics program to manipulate shaped and colored building blocks ("world of toy blocks") with a magnetic arm. The program could accept commands in natural language such as "Find a block which is taller than the one you are holding and put it into the box." For this purpose, the building blocks with their properties and location information were represented in data structures (Mainzer 2019).

1.3 The Third Phase of AI: The Middle of the 1970s to the Middle of 1980s

In the third phase of AI, from the mid-1970s to mid-1980s—knowledge-based expert systems came to the fore; the first practical applications were promising. Delimited and manageable specialized knowledge of human experts, such as engineers and doctors, should be provided for everyday use (Mainzer 2019).

These knowledge-based expert systems are AI solutions; they store the knowledge about a special field and can retrieve that knowledge. The systems can identify concrete solutions or provide diagnoses. In contrast to the human expert, the knowledge of an expert system is limited. It has no general background knowledge, no memories, feelings, or motivations, which can be transferred from person to person. For these AI systems, knowledge is the key factor in the representation of an expert system. It can be distinguished between two types of knowledge: knowledge of facts in the field of application, which are described in textbooks and magazines, and heuristic knowledge, on which judgment is based, and any successful problem-solving practice in the area of application (Mainzer 2019).

1.4 The Fourth Phase of AI: The Beginning of the 1990s

In the latest phase of AI, beginning in 1993 after the second AI winter of around 1990 (WIPO 2019a), optimism about AI returned. Thanks to Moore's Law, the computational power increased, and memory capacity could be bought for a reasonable price, and thus AI became data driven. Important milestones were reached. In 1997, IBM's DeepBlue beat world champion Kasparov at chess; 5 years later (in 2002) Amazon used automated systems to provide product recommendations. Moreover, in 2011, IBM's Watson beat human champions at the TV quiz Jeopardy (Buxmann and Schmidt 2019).

During recent years, connectivity between devices—mobile and fixed—was an additional driver for AI applications. In 2012, Google developed driverless cars that navigate autonomously. Based on the high availability of computational power and memory, machine learning algorithms (e.g., based on neural networks) are used successfully (WIPO 2019a).

AI Timeline [According to Buxmann and Schmidt (2019), Getsch (2018), and WIPO (2019a)]

1950:	*Turing Test* by Alan Turing
1956:	"*Dartmouth conference*" and AI is founded as an academic discipline
1956–1974:	The golden years of AI, *logic-based problem-solving* approaches
1966:	*ELIZA*
~1975:	First "*AI winter*" due to high expectations and the limited capacities
1980–1987:	New successes with *knowledge-based expert systems*
~1990:	Second "*AI winter*," the sudden collapse of the specialized hardware industry
1993–2011:	Optimism about AI returns and increases. Increased computational power *AI becomes data-driven*
1997:	IBM's DeepBlue beats world champion Kasparov at chess
2002:	Amazon uses automated systems to provide recommendations
2011:	Apple releases Siri; IBM's Watson beats human champions at TV quiz Jeopardy
2012–today:	Increased availability of data, connected-ness, and computational power *Machine learning breakthrough* (neural networks, deep learning)
2012:	Google driverless cars navigate autonomously
2016:	Google AlphaGo beats a world champion in the complicated board game Go

2 Overview of AI Applications and AI-Based Business Models

2.1 General Forms of AI

The *Encyclopedia Britannica* states, "artificial intelligence (AI) is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings." Intelligent beings are those that can adapt to changing circumstances. Rich et al. (2009) defined "Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better." This makes the point that AI is a kind of competition between human and machine and that AI is relative in terms of forms and performance. In 1996, the victory of Deep Blue in chess against Kasparov was treated as a breakthrough of AI, followed by victories in 2011 in Jeopardy and in 2016 against the Korean world champion in Go (Getsch 2018).

In general, AI can be distinguished between weak AI and strong AI:

Weak AI or Narrow AI Weak artificial intelligence is a form of AI specifically designed to be focused on a narrow task but to seem very intelligent at it. It contrasts with strong AI, in which an AI is capable of all and any cognitive functions that a human may have, and is in essence no different from a real human mind. Weak AI is never taken as a general intelligence but rather a construct designed to be intelligent within the narrow task that it is assigned (Kumar 2018).

A good example of a weak AI is Apple's Siri, which has the Internet behind it serving as a powerful database. Siri seems very intelligent, as it can hold a conversation with actual people, even giving snide remarks and a few jokes, but it operates in a very narrow, predefined manner. However, the "narrowness" of its function can be evidenced by its inaccurate results when it is engaged in conversations that it is not programmed to respond to.

Robots used in the manufacturing process can also seem very intelligent because of the accuracy and the fact that they are doing very complicated actions that could seem incomprehensible to a normal human mind. That is the extent of their intelligence; they know what to do in the situations that they are programmed for, and outside of that, they have no way of determining what to do. Even AI equipped for machine learning can only learn and apply what it learns to the scope it is programmed for (techopedia 2019).

Strong AI Featured in many movies, strong AI acts more like a brain. It does not classify but uses clustering and association to process data. In short, it means there is not a set answer to your keywords. The function will mimic the result, but in this case, we aren't certain of the result. Like talking to a human, you can assume what someone would reply to a question with, but you do not know. For example, a machine might hear "good morning" and start to associate that with the coffee maker turning on. If the computer has the ability, it could theoretically hear "good morning" and decide to turn on the coffee maker (Kerns 2017).

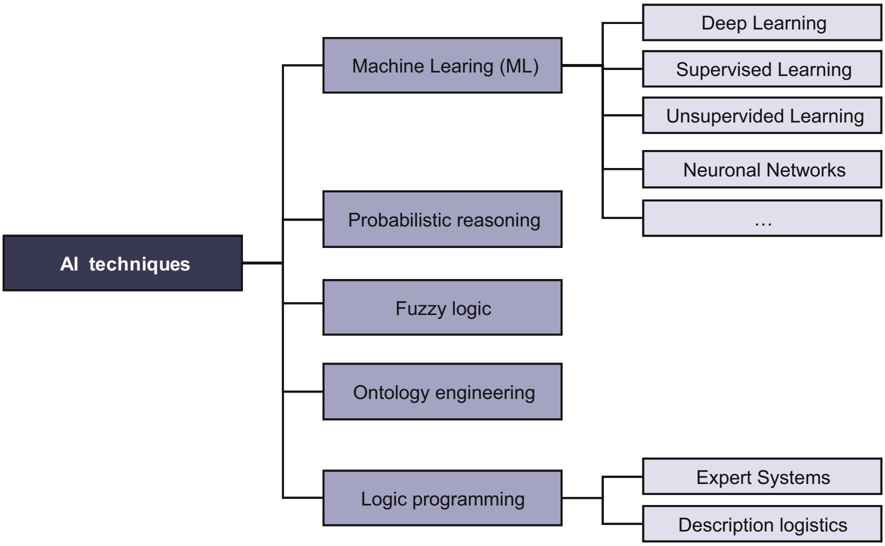

Fig. 1 AI techniques (own illustration according to WIPO 2019a)

In strong AI, the machines can think and perform tasks on their own just like a human being. There are still no proper existing examples for this, but some industry leaders are keen on getting close to building a strong AI, which has resulted in rapid progress (Kumar 2018).

2.2 *Common AI Techniques*

The five core AI techniques, machine learning, probabilistic reasoning, fuzzy logic, ontology engineering, and logic programming, are used to implement an AI solution (Fig. 1).

The AI techniques in detail:

Machine Learning (ML) enables IT systems to recognize patterns and laws based on existing data and algorithms and to develop solutions. Artificial knowledge is generated from experience. The knowledge gained from the data can be generalized and used for new problem solutions or the analysis of previously unknown data.

To enable software to learn independently and identify solutions, it is necessary that humans act in the first step. For example, the systems must first be supplied with the leading data. Rules should also be defined for the analysis of the data and the identification of data samples. If suitable data is available and rules are defined, machine learning systems can, among other things, do the following: find, extract, and summarize relevant data; forecast by the analyzed data; calculate probabilities for specific events; adapt independently to developments; and optimize processes based on recognized patterns (Litzel 2016).

Algorithms play a central role in machine learning. Algorithms are responsible for recognizing patterns and generating solutions and can be divided into various learning categories, including:

- *Deep learning*, with a class of optimization methods for artificial neural networks that have numerous hidden layers between the input layer and the output layer and thus have a large internal structure
- *Supervised learning*, an approach where learning a function that maps an input to an output based on example input–output pairs
- *Unsupervised learning*, where the systems learn from test data that has not been labeled, classified, or categorized
- *Neuronal networks*, networks of artificial neurons, which follow a biological model

The main characteristic of machine learning is that, besides program code and algorithms, learning or input data is required to train the AI.

Further important AI techniques include:

- *Probabilistic reasoning*, an approach that is using logic and probability to handle uncertain situations
- *Fuzzy logic*, a form of many-valued logic in which the truth values of variables might be any real number between zero and one inclusive to handle the concept of partial truth, in contrast to the Boolean logic
- *Ontology engineering* to find a formal representation of knowledge within a domain
- *Logic programming*, a type of programming paradigm that is largely based on formal logic

2.3 Functional AI Applications

Besides the techniques, each AI solution addresses a defined functional AI application (e.g., the processing of natural language, the recognition of pictures or videos, or the prediction of future scenarios). Thus, the most important functions of AI applications are described below (Fig. 2):

Speech Processing Speech processing is the study of speech signals and the processing methods of signals. The signals are usually processed in a digital representation so that speech processing can be regarded as a special case of digital signal processing, applied to speech signals. Aspects of speech processing include the acquisition, manipulation, storage, transfer, and output of speech signals. The input is called *speech recognition*, and the output is called *speech synthesis*.

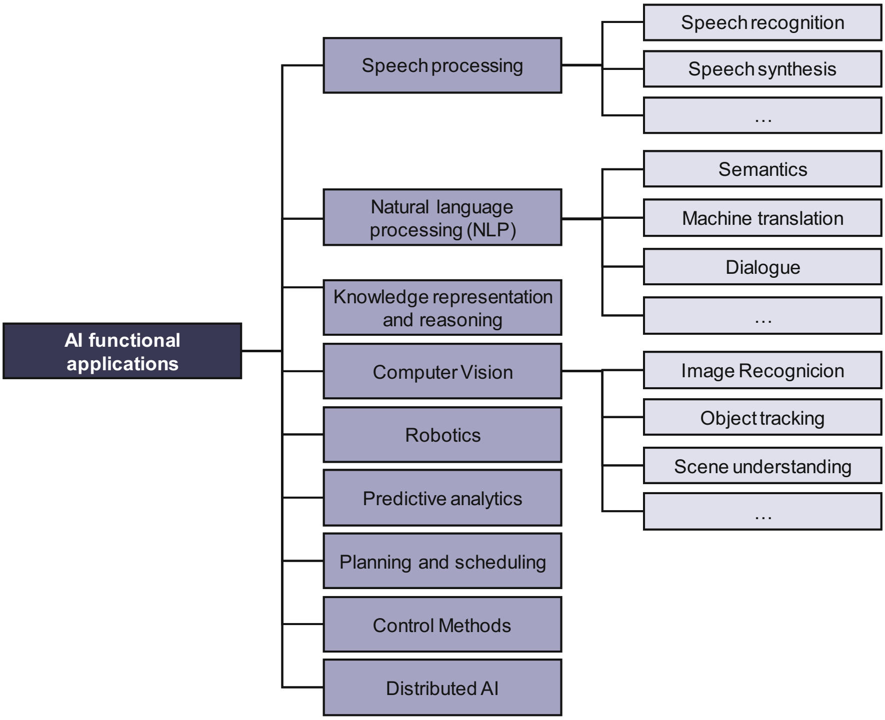

Fig. 2 Functional AI applications (own illustration according to Mills 2016; WIPO 2019a)

Natural Language Processing Natural language processing (NLP) is broadly defined as the automatic manipulation of natural language, such as speech and text, by software. One of the well-known examples of this is email spam detection, as we can see how it has improved in our mail system.

Knowledge Representing and Reasoning These serve to formally map knowledge in knowledge-based systems; knowledge represented in this way is called a knowledge base. The methods of knowledge representation are applied to implement expert systems and machine translation programs.

Computer Vision This is a field that enables the machines to see. Machine vision captures and analyzes visual information using a camera, analog-to-digital conversion, and digital signal processing. Computer vision can be compared to human eyesight, but it is not bound by the human limitation, which can enable it to see through walls (now that would be interesting if we can have implants that allow us to see through walls). Computer vision is usually achieved through machine learning to get the best possible results, so we could say that these two fields are interlinked.

Robotics A field of engineering focused on the design and manufacturing of robots. Robots are often used to perform tasks that are difficult for humans to perform or perform consistently. Examples include car assembly lines, in hospitals, office cleaner, serving foods, and preparing foods in hotels, patrolling farm areas, and even as police officers. Recently, machine learning has been used to achieve certain good results in building robots that interact socially.

Predictive Analytics This is an area of statistics that deals with extracting information from data and using it to predict trends and behavior patterns. The enhancement of predictive web analytics calculates statistical probabilities of future events online.

Planning and Scheduling This is a branch of artificial intelligence that concerns the realization of strategies or action sequences, typically for execution by intelligent agents, autonomous robots, and unmanned vehicles.

Control Methods These are used to check and evaluate the status of a system, as well as to steer the behavior of a system (e.g., in autonomous driving).

Distributed AI (DAI) or Decentralized AI This is used to develop distributed solutions for problems. DAI is closely related to and a predecessor of the field of multi-agent systems.

2.4 Application Fields of AI

Regarding the application fields of AI, there are two main approaches to structuring the application fields. First, *industry-specific AI applications*. Most AI applications have a clear industry focus and are included in this category (e.g., banking and finance, energy management, industry and manufacturing, telecommunications, life and medical sciences, transportation, retail, or government). Second, *cross-industry AI applications*. A smaller number of AI applications address a more functional topic and can be used across numerous industries. Examples include document management, security applications, and network solutions.

In both cases, for AI solutions in a dedicated application field, the solution uses an AI technique and addresses a functional AI application. For example, a Chatbot used in the retail sector to enable a customer self-service solution in an online shop is a natural language processing application and uses a supervised machine learning technique.

3 State of the Art and (Newer) Innovations in AI-Based Business Models

3.1 Classification of AI-Based Business Models

There is currently no clear established standard on how to classify new AI-based business models. Some authors suggest classifying by technology, and others by domains or by a combination of both. Corea (2017, p. 21) recommends viewing the AI sector as similar (in terms of business models) to the biopharma industry: expensive and long R&D; long investment cycle; low probability of enormous returns; and concentration of funding toward specific phases of development. There are two main differences between those two fields: the experimentation phase, which is much faster and painless for AI, and the (absent) patenting period, which forces AI to continuously evolve and to use alternative revenue models (e.g., freemium model).

In the following, two different, newer classifications of AI-based business models are discussed. First, a classification by Corea (2017) in a matrix along the two business-relevant dimensions: monetarization ability and defensibility of the business model. Second, a more technical business model classification by Nguyen-Huu (2018) considering the degree of integration of AI into the existing IT landscape.

3.2 Classification in a Monetarization–Defensibility Matrix

Corea (2017) found, based on his observation in the market, that categorization of AI-based business models can be summarized into a matrix, plotting the groups concerning short-term monetization (STM) and business defensibility (Fig. 3). The resulting four clusters are characterized as follows (Corea 2017, p. 24):

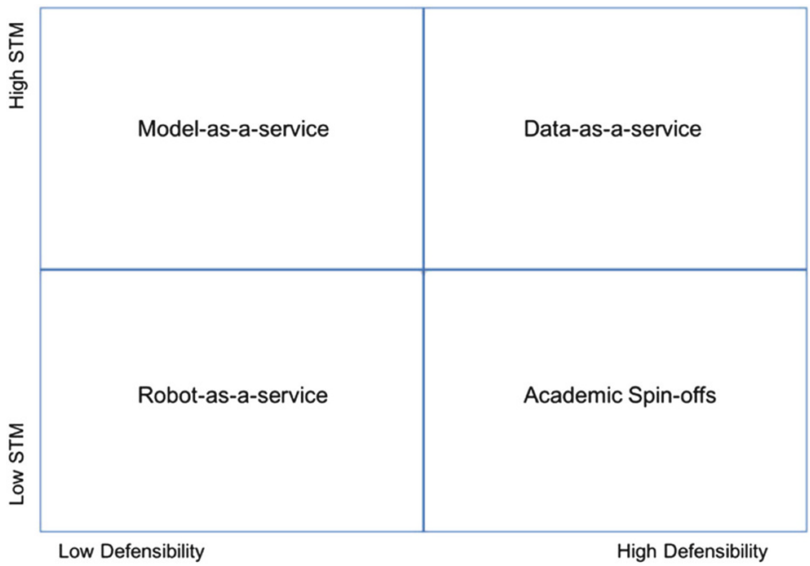

Fig. 3 Artificial intelligence classification matrix (Corea 2017, p. 25)

1. *Academic spin-offs*: These are the more long-term research-oriented companies, which tackle problems that are difficult to break. The teams are usually highly experienced, and they are the real innovators who make breakthroughs that advance the field.
2. *Data-as-a-service (DaaS*): This group includes those companies that collect specific huge datasets or create new data sources connecting unrelated silos.
3. *Model-as-a-service (MaaS)*: This is the most widespread class of companies, and it is made of those firms that are commoditizing their business models as a stream of revenues. They can appear in three different forms:
   - *Narrow AI*: Focus on solving a specific problem through new data, innovative algorithms, or better interfaces.
   - *Value extractor*: Extract value and insights from data, usually working together with existing IT systems.
   - *Enablers*: Enabling the final user to do her analysis, allowing companies to make daily workflows more efficient, or eventually unlocking new opportunities through the creation of intermediate products (e.g., applications).
4. *Robot-as-a-service (RaaS)*: Virtual and physical agents that people can interact with. Virtual agents and Chatbots cover the low-cost side of the group, while physical world systems (e.g., self-driving cars, sensors), drones, and actual robots characterize the capital and talent-intensive side.

3.3 Classification Along the Degree of Integration

A newer, alternative classification of AI-based business models was defined by Nguyen-Huu (2018). During the last 2 years, Nguyen-Huu has observed three emerging AI business models that consider the degree of integration into the existing IT system and solution landscape (according to Nguyen-Huu 2018):

1. *AI on-top business model*: In this business model, the AI solution sits seamlessly on top of other systems, like a customer relationship management (CRM) solution or an enterprise resource planning (ERP) system. The AI accesses to data flowing through these systems and realizes an improvement of business over time. Many AI start-ups fit into this model. For example, Chorus AI and Gong both tap into Salesforce using AI to optimize a company's sales practices. Customer support software Solvy sits on top of Zendesk or ServiceCloud and automates replies to support tickets. Sift Science uses machine learning to reduce customer fraud, like payment abuse or fake content.
2. *AI-enhanced process business model*: Here deploying a new AI product does not change the existing workflow, but it increases the effectiveness of current workflows by integrating AI into them. These are deep integrations and require lots of implementation efforts. Examples for this model are AI solutions like IBM's Watson, Ayasdi, and H2O. In this model, AI is playing across various

industry verticals, and these solutions can help to improve the core business operations. Take IBM's Watson for example; it analyzes big-data patterns in real time, flagging insights that might be worth responding to. Watson is being used to help prepare tax returns and even manage building elevators through complex sensors transmitting data back to computers.

3. *AI solution stand-alone business model*: The AI technology changes an entire workflow by introducing an AI-infused, better-way-to-complete-a-business-process. AI "owns" the experience end to end, with very little human-required assistance, giving algorithms the full control over the experience. Example companies include autonomous cars and drone companies, like Kespry, whose aerial drones collect data for construction, mining, or insurance purposes. After a storm, Kespry drones can assess roof damage, so there is no need to send an insurance adjuster on top of your roof. Since the data is directly sent to the cloud and analyzed using AI-powered computer vision, the insurance company can estimate claims data almost immediately.

3.4 Implications from AI-Based Business Model Classifications for IP

Both discussed classifications for AI-based business models were derived quite pragmatically based on observations in the market. This is a strength and weakness at the same time. If the two are taken as a basis, it can be summarized that regarding the importance of IP for the business model, in almost all business models two components play a central role: on the one hand, the AI algorithms and technologies itself, and, on the other hand, the data to which these AI algorithms and technologies are applied. For the business success of an AI-based business model, both are of crucial importance and often inseparable.

Therefore, in the following, we examine the role of IP in AI-based business models—in most cases consisting of both algorithms and data—and how effective IP protection can be achieved.

4 The Role of IP in AI-Based Business Models

4.1 Formal and Informal Protection Strategies for Business Models

An important aspect of innovating is how to capture value (e.g., profits). There has been an evolution in research, starting with Teece (1986) who is considered one of the first to describe the mechanisms of value capture in the context of technological innovation. Other researchers have also included product and process innovation (Chesbrough and Rosenbloom 2002) and have discussed the protection of intellectual property (IP) in the economic context (Cohen et al. 2000; Dosi et al. 2006; Harabi 1995). For example, the knowledge-intensive business service firms protect their inventions on the joint use of informal and formal protection strategies (Amara et al. 2008; Bader 2008). In general, formal and informal protection mechanism have to complement each another and are both fundamental for capturing value from innovation (Arora and Ceccagnoli 2006; Hall and Ziedonis 2001; McGahan and Silverman 2006; Pisano 2006; Rivette and Kline 2000).

Also, with regard to business models, value capturing has been discovered as being key to the sustainable profitability of companies (Chesbrough 2007; Teece 2010; Zott et al. 2011). There are two main reasons (Lepak et al. 2007; Priem 2007): First, value creation is no longer purely tied to company and industry boundaries (Amit and Zott 2001), and it has become important for the individual market player to understand where value creation takes place (Gassmann et al. 2015). Second, the question has arisen how to protect the created value. About the profiting from innovation framework (Chesbrough et al. 2006; Teece 2006), Desyllas and Sako (2013) indicate that formal IP right protection methods and strategies should be complementary. While formal IP strategies are mainly effective for short-term purposes, specific complementary assets are needed to capture long-term value. For example, the fast-moving consumer goods giant Nestlé applied for its coffee capsule business Nespresso formal IP protection methods in the short term to build up a premium position and today is mainly relying on informal IP protection strategies in the long term (Brem et al. 2016).

Which protection strategy to choose also depends on factors such as the *type of innovation*, *the size and market share* of the firm, and the firm's *R&D activities*. In that context, Gallié and Legros (2012) evaluated seven forms of formal and informal protection strategies: patents, design rights, trademarks, and copyrights as formal protection strategies and trade secrets, the complexity of products and manufacturing process, and lead-time advantage as an informal protection mechanism. They define the protection strategies as follows:

Formal IP Strategies

1. *Patents*: an inventor, who registers a patent, receives the right to prohibit the imitation or use (own use or selling it) of his invention by others for a limited time. This allows the inventor to realize monopolistic prices when exploiting the innovation. However, when registering a patent, the inventor must disclose the information around the innovation and hence enables competitors to "invent around" the patent. This drawback could overshadow the benefits of realizing monopolistic prices for innovation.
2. *Design rights*: design rights protect the visual appearance of objects such as the shape, the colors, and the materials. To register a design, two requirements must be met. First, it has to be new, which means that no identical design was published before registration. Second, it has to be unique, which means that the overall appearance must differ from other designs.
3. *Trademarks*: a trademark is a sign, symbol, design, or expression that distinguishes products or services of a company from the ones of other companies.

Although a trademark is not limited in time, the registering company needs to renew it periodically.

4. *Copyrights*: a firm which registers copyright receives exclusive rights for original work and hence obtains the power to determine who may financially benefit from it.

Informal IP Strategies

1. *Trade secrets*: trade secrets cover non-public information and enable firms to obtain a competitive advantage over companies that do not own the information. This includes formulas, methods, techniques, processes, and instruments. Firms have to take action to maintain secrecy about the information.
2. *The complexity of products and manufacturing processes*: the complexity of products and manufacturing processes depicts an instrument to capture value from innovation. If a product or service consists of complex processes, technologies, or components that are necessary to build and distribute it, this complexity grants the firm a competitive advantage, since the offerings are more difficult to imitate.
3. *Lead-time advantage*: in this context, the lead-time advantage is established if firms innovate faster than their competitors. This leads to competitive advantages that enable them to capture value from their innovation.

Protecting what kind of intellectual property has become a relevant aspect depending on which business model is being operated and on which elements of the value creation should be protected to gain high-value creation leverage. In a recent study based on an evaluation of different business model types, it could be underlined that different business models need different optimization and complementation of formal and informal IP protection strategies (Bonakdar et al. 2017).

4.2 Challenge to Apply Formal IP Strategies to AI

Applying formal IP strategies to AI-based innovations faces a challenge when it comes to patenting AI-based inventions. The two main reasons are that, on the one hand, algorithms play a major role when designing AI concepts. As algorithms "as such" are considered as mathematical methods, they are per se excluded from patentability under the main patent legislation regimes. On the other hand, AI concepts are often directed to automate or conduct tasks and activities that are currently performed by the human mind—also a reason for patent ineligibility either for being just considered as a theoretical concept or due to lack of novelty.

However, many of the current AI-based inventions are based and implemented as software. As is the case in other fast developing technical growth sectors. For example, more than 80% of the value added in the ICT sector is based on software and related services (OECD 2017). So, relating patent legislation and practices have already built up during the last decades how to deal with software-based inventions:

In *Europe*, under the European Patent Convention AI as a mathematical method per definition is excluded from patentability when claimed as such. However, if a method involves technical means (e.g., a computer) or a device, its subject matter may have a technical character as a whole and for that reason is not excluded from patentability (so-called *computer-implemented inventions*, CII): "The element in the technology which is new and inventive is actually a changed computerized algorithm or control mechanism which is responsible for bringing about an improved technical effect" (EPO 2013, 2017; see also Glossary for CII). When assessing patentability, the European Patent Office (EPO) applies the so-called two-hurdle approach for "mixed-type inventions" and checks whether "the AI method (steps) contributes to the technical character of the invention?" (EPO 2018a). In this context, the EPO also recently updated their Guidelines for Examination with a specific section on "Artificial intelligence and machine learning," providing guidance on the assessment of whether an invention on AI and machine learning is based on the necessary "technical character" to be patentable and would feature examples relating to AI as well as detailed information on the technicality of CII based on decisions by the EPO's boards of appeal (EPO 2018b).

The *US* patent eligibility so far presents a challenge, too, but due to a different legal philosophy. This is because, in the USA, abstract ideas are not considered patentable. Furthermore, the mere use of a computer to implement an abstract idea is not sufficient to gain patent eligibility (EPO 2018a).

As the law firm Baker McKenzie elaborates (Flaim and Chae 2019): In the USA, the biggest legal hurdle to obtaining a patent on an AI invention is arguably 35 United States Code (USC) §101, which limits patent-eligible subject matter to a "process, machine, manufacture, or composition of matter," and is interpreted by the courts as excluding abstract ideas, laws of nature, and natural phenomena. The standard on this patent subject matter eligibility requirement became more stringent for software and "computer-implemented" inventions with the US Supreme Court's 2014 decision in *Alice Corporation v. CLS Bank International*, which employed a heightened two-step test:

1. Determining whether the invention is directed to a patent-ineligible concept, such as an abstract idea; and if so,
2. Determining whether the claimed elements provide any "inventive concept" that would transform the abstract idea into a "patent-eligible application".

The Alice Court held that the patent claims on "intermediated settlement" are directed to an abstract idea without any inventive concept because each of their elements is a "well-understood, routine, conventional" activity, failing to do more than "require a generic computer to perform generic computer functions." Lower court decisions, such as DDR Holdings, LLC v. Hotels.com, LP, Enfish, LLC v. Microsoft Corp., BASCOM Global Internet Services, Inc. v. AT&T Mobility LLC, and Berkheimer v. HP Inc., among others, provide meaningful insights into the application of *Alice's two-step test*, and the United States Patent and Trademark Office's guidelines, particularly the "2019 Revised Patent Subject Matter

Eligibility Guidance," can bring further clarity on subject matter eligibility (USPTO 2019).

"Abstract idea" in U.S. jurisprudence courts' invalidations of patent claims for covering subject matter that could be performed through an "ordinary mental process" "in the human mind" or by "a human using a pen and paper" under the Alice Corporation v. CLS Bank International test. This creates tension with patenting AI inventions because the goal of AI is often to automate or better perform human tasks and activities.

Other jurisdictions have different standards on subject matter eligibility, as discussed in the USPTO's "Patent-Eligible Subject Matter: Report on Views and Recommendations from the Public," issued in July 2017:

- In *Japan*, a software invention is patentable if its information processing aspects are required to be "specifically implemented by using hardware resources." Many view software inventions being patent eligible, so long as their claimed inventive steps are expressly tied to hardware.
- In *China*, according to the examination guidelines revised in April 2017, "the computer program-related invention" that has "technical characteristics will not be excluded from patentability." This revision is viewed by many as a broadening of the scope of patent-eligible subject matter.
- The *Korean* Intellectual Property Office's guidelines state that computer programs per se are not patent-eligible, but they also "indicate that if computer software is claimed in conjunction with hardware, then the combination, the operating method of the combination, and a computer-readable medium containing the software that implicates the combination is patent eligible." The Republic of Korea recently introduced an accelerated examination for patent applications pertaining to AI and other specified emerging technology fields.

Generally speaking, software inventions can be patented in these non-US offices if they are implemented with or sufficiently tied to hardware. Thus, some believe that the patent subject matter eligibility standard outside the USA might be less stringent than the Alice framework, although others believe that the recent developments indicate a convergence of the Alice framework, particularly with respect to its second prong, and the European practice.

4.3 Status quo in Patenting AI-Related Innovations

As already indicated, AI-related innovations are often based on software and computer-implemented inventions, respectively. They might be directed to one or more specific AI application fields. Based on earlier and current legislation, various companies and research organizations have started filing patents also in the field of AI. As displayed in Fig. 4 (AI-related patent families and scientific publications by

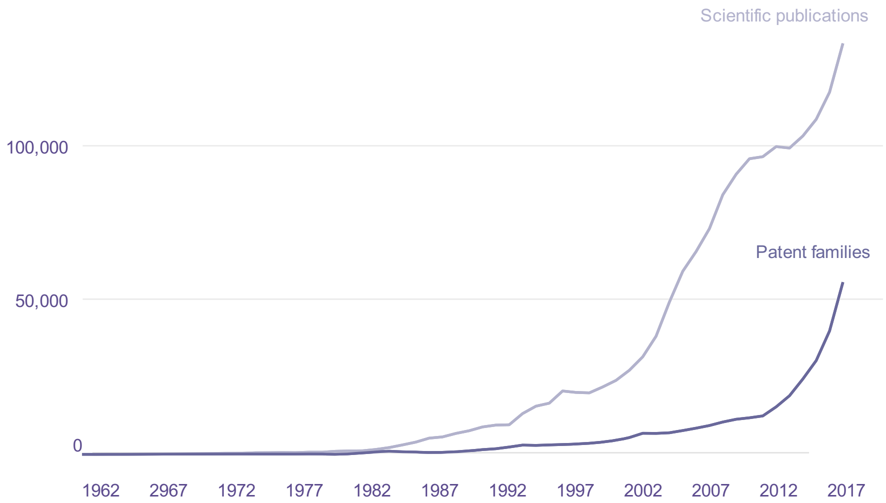

Fig. 4 AI patent families/scientific publications by the earliest publication year (WIPO 2019a)

earliest publication year), nearly 340,000 patent families[1] have been filed and published since the 1960s. One can also see that AI has become a major field in science with a total of more than 1.5 million papers published up to mid-2018. While the number of scientific publications increased significantly by the beginning of the 2000s (with an average annual growth rate almost doubling to 18% between 2002 and 2007), it took another 10 years for the patent publications to lift off (with an average annual growth rate of 28% between 2012 and 2017). A reasonable interpretation is that basic research primarily results first in scientific publications, while development efforts with regard to industrial applications take some time and result in patent publications.

Patent applications directed to specific application fields have been emerging since the mid-1990s (Fig. 5).[2] The top application fields for which patent protection is sought are transportation and telecommunications. Please note that AI-related inventions are regularly directed to several application fields.

[1]The terms "patent family," "patent application," "patent filing," or "invention" may be used interchangeably, referring to the representative patent family member and the corresponding invention. A patent family may include members for which patents have been granted, others not granted, or still under patent examination.

A patent family includes all those patents in different offices that relate to the same or similar technical content. The earliest application in the family has what is known as the priority number, and other applications in the family share one or more pieces of priority data for the purposes of novelty and inventive step. There are different definitions of patent families; for the displayed data and charts, patent families are used that are grouping together the same invention sharing the exact priority data seeking patent protection in different jurisdictions (WIPO 2019).

[2]Note: A patent may refer to more than one category.

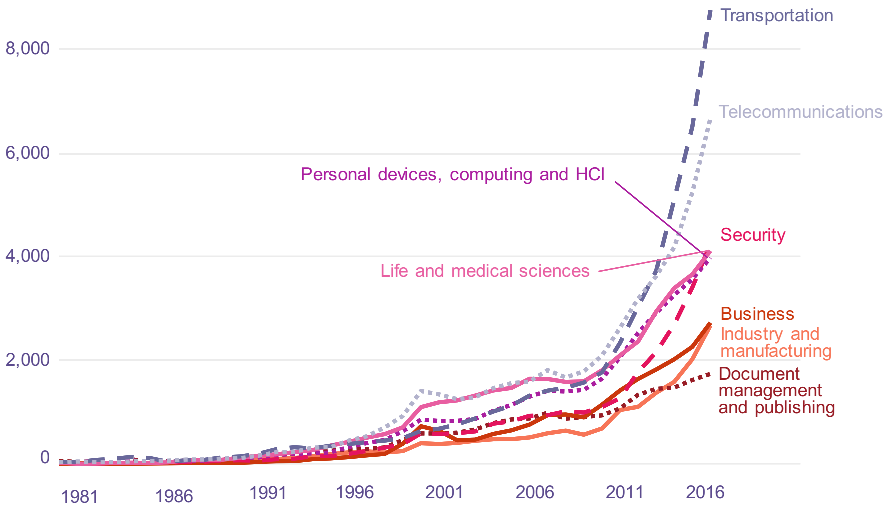

Fig. 5 Patent families for application field categories by earliest priority year (WIPO 2019a)

Not surprisingly, within the top 30 patent applicants, there are 26 companies[3] and 4 universities or public research organizations (Fig. 6), which is led by Asian players in: CAS (China) and ETRI (Republic of Korea) rank first and second in patent filings among universities and public research organizations (Fig. 7).

Following the trends in science, industrial applications of AI-related technologies are growing rapidly, with dominance by US-based and Asian (especially Chinese) corporations.

4.4 IP Protection Strategies for AI-Based Business Models

Current AI research and innovation is based on large monetary investments. Alone, the European Union wants to increase the overall investments (public and private sectors) within the EU region in AI to at least 20 billion euros per year beyond 2020 (EC 2018).

According to WIPO data, almost 3000 companies active in AI have received funding (almost half of all AI active companies), representing about US$46 billion in funding. Also, M&A has become a means to acquire AI-based technologies, data access, and related patent portfolios. Almost 500 companies have been acquired, with more than half of them since 2016. This represents a great exit and co-funding environment for start-ups. Given the high investments in AI technologies and their

[3]Note: Fujitsu includes PFU; Panasonic includes Sanyo; Alphabet includes Google, Deepmind Technologies, Waymo, and X Development; Toyota includes Denso; and Nokia includes Alcatel.

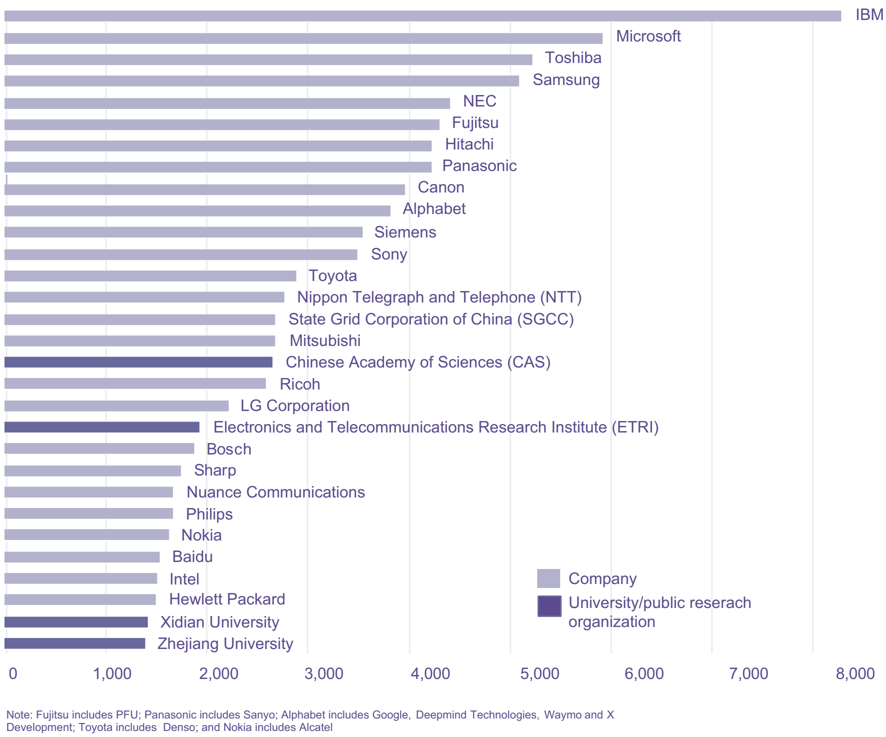

Fig. 6 Top 30 patent applicants by the number of patent families (WIPO 2019a)

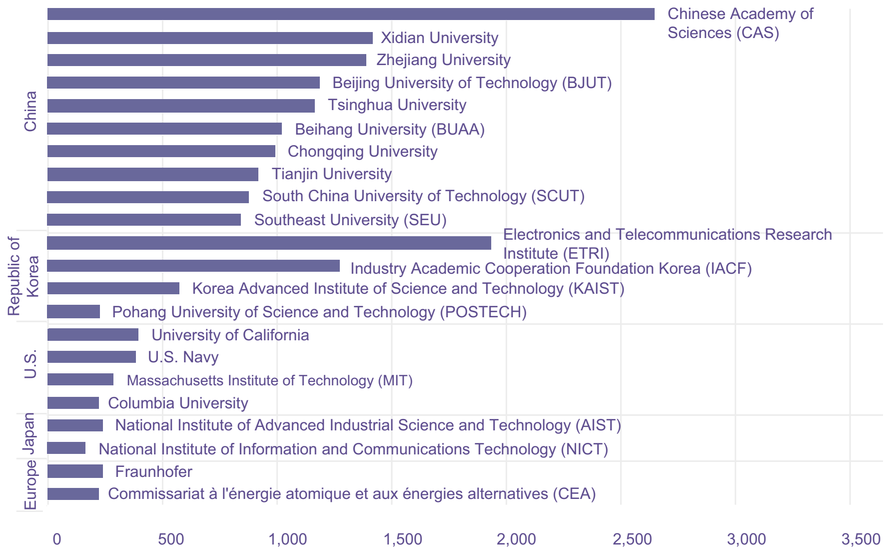

Fig. 7 Top patent applicants among universities and research organizations (WIPO 2019a)

applications, it is obvious that companies and investors are attempting to protect and monetarize their investments. While out of research, over 1.6 million publicly available scientific publications have emerged, 340,000 AI-related inventions have been claimed for patent protection since artificial intelligence emerged in the 1050s. Enforcing patents has also emerged into the field of AI, with thousands of AI-related patent families being mentioned in litigation cases (WIPO 2019a).

Also, in the field of AI IP protection, mechanisms are used and enforced to secure and to monetarize investments. Below, we present some of the applied key protection strategies for formal and informal AI-related IP:

1. Protectability of AI-based inventions and innovations with *formal IP means*:
   - *AI algorithms → Patents*: There are typically three types of AI-related inventions (EPO 2018a) that are eligible for patent protection (provided that the general legal requirements for patentability of software can be met, e.g., the two-hurdle approach to testing the technical character of the invention before the EPO in Europe or the passing of the Alice Corporation v. CLS Bank International test in the USA):
     – *Core AI*, including the challenge that *algorithms as such*, may not be patentable (e.g., if not implemented in an applied field and consequently being considered as non-patent-eligible mathematical methods)
     – *Trained models/machine learning*, including the challenge to claim variations and ranges
     – *AI as a tool* in an applied field, defined via technical effects
   - *AI code → Copyright*:
     – *AI software program code* is generally considered as non-patent-eligible subject matter but is eligible for copyright protection.

2. Protectability of AI-based inventions and innovations with *informal IP means*:
   - *AI data → Trade secrets:*
     – *Datasets* (e.g., categorized training data for supervised learning may be classified and kept secret)
     – *Data protection rules* (e.g., the General Data Protection Regulation (GDPR) in the European Union, which may limit the exchange of or access to data).

In contrast to the abovementioned IP protection strategies that aim to gain *differentiation* by gaining exclusivity, there is a second applied approach that is based on a *standardization* by access from and to the public domain. In the recent models of innovation management, both approaches have been practiced by innovation champions in parallel to optimize innovation speed and get access to standards, but still to monetarize their own R&D investments (Bader 2007; Gassmann and Bader 2017).

However, when developing AI techniques there are two major challenges: (a) to develop the AI systems and algorithms from a technical point of view and (b) to have access to qualified datasets (e.g., to optimize the AI algorithms or to train the AI systems). Access to datasets is already considered as a major competitive advantage between legal systems (e.g., China compared to the USA), but also for investors that invest in start-ups: Which dataset is available? How much of the investment needs to get first burned for qualifying raw data? For public research organizations, it might be even more difficult to get data access due to limited financial budgets or data protection rules (e.g., in the field of life sciences).

Within the public domain, there might be open access to algorithms and software code (e.g., TensorFlow and scikit-learn, which are available on the collaborative developer platform GitHub) (Stone et al. 2016), but also to datasets (e.g., for training purposes). Furthermore, public research organizations might dedicate their outcomes to the public domain [e.g., for fundamental research, like MIT-IBM Watson AI Lab (US$240 million funding in 2017), or due to a philanthropic approach, like MILA (US$3.4 million funding from Alphabet/Google in 2016; see also Box)].

Open Source at Mila, Myriam Côté, Montréal Institute for Learning Algorithms (Mila)

The research community at the core of our model has a culture of open collaboration, open research, open source code, open libraries, and open datasets. This culture is reflected in the general policy of our institute regarding partnerships: We are very reluctant to engage in industry projects with IP constraints, which often jeopardize the free flow of information, preventing open discussions among researchers and limiting the number of publications that can be made available to the community at large. Such constraints are often application-specific and result in tying our innovations to IP that belongs to a specific company. The pace of technological progress in such environments is, inevitably, slower. All players have less to gain, despite the short-term gain that exclusivity may appear to offer.

For this reason, the principal mechanism through which we welcome financial support from research partners is through philanthropic donations.

We share all of our code and all of our new algorithmic strategies in the public domain by publishing promptly and refraining from writing patents. This open policy necessarily leads to a healthy and fast-paced research environment, a characteristic of which our partners are increasingly appreciative. They too recognize that players in this disruptive domain need to adopt agile philosophies and question the premises behind traditional models of industrial innovation.

(*Extract from* WIPO 2019a)

For entrepreneurial companies it is, therefore, a comparative advantage when researching and/or innovating in the field of AI to practice both standardization in the open source public domain (e.g., to speed up development or to pool and enlarge datasets) and (!) differentiation by exclusivity applying formal and informal IP protection strategies to capture value (e.g., to leverage competitive advantages or to get access to VC investments) (Fig. 8).

4.5 Conclusions and Managerial Implications

We have given a short overview of the history of artificial intelligence (AI) technologies displaying AI's long tail back to its beginnings in the 1950s. Until today, where we are confronted with a current AI boom that is fundamentally enabled by so far enriched computing capacities and fueled by the availability of large and specific datasets, both public or exclusive. AI has emerged not as a single technology mantra but rather as multiple sets of techniques, e.g., machine learning or deep learning based on multilayered neuronal networks being specifically used within certain application fields, e.g., for speech processing, computer vision, or robotics.

Although basic research is still ongoing and scientific publications have significantly increased since the 2000s, industry-sector-specific and cross-industry AI applications are have become increasingly common since the 2012s, as patent application numbers clearly suggest. AI is increasingly used and applied in business models, ranging from weak AI and narrow AI for limited tasks up to strong AI in the (potentially near) future.

There has been various research and practical evidence that complementary formal and informal protection strategies are necessary for effective value capture in business model innovation. We suggest that for AI-based business models, especially formal IP protection means [patents (e.g., for applied AI algorithms), copyrights (e.g., for AI code)], and informal IP protection [trade secrets (e.g., for AI datasets)] play a significant role. As the current systems primarily clarify how AI can be patented as being considered as software, applying AI algorithms, it remains to legislation and professionals to tackle the remaining legal, practical, and ethical challenges, especially when it comes to patent protecting AI-based methods and systems.

From an innovator's point of view, the main challenge is how to balance public commons (e.g., to get access to specific datasets and/or specific AI algorithms), while the innovators' basic question is *how* and *where* to capture value/comparative differentiation (e.g., to monetarize the ownership/access to specific datasets). Our findings integrate findings from R&D cooperation and cooperation models and practices, as well as the above outlined formal and informal protection strategy complementary.

About entrepreneurship and start-ups, the accelerating progress of AI technologies has made it necessary to cope with a new, higher level of acceleration in business development, requiring a tremendous concentration of activities—attracting funding, attracting AI software engineers—at a speed not seen before,

Proprietary Innovation:

- **exclusive ownership**
- **who pays owns case**
- **owner can license, sell, sue, use**
- **no shared income**

Bought Control Model:

- ❖ no loss of ownership, regardless of payment
- ❖ full right to use, license, etc.
- ❖ no accounting problems
- ❖ lower admin overhead

➔ **DIFFERENTIATION**

Open Innovation:

- **jointly own**
- **who pays controls case**
- **all owners license to public for free**

Free Public Commons Model:

- ❖ ownership supports commons
- ❖ full right to use, license etc.
- ❖ no accounting problems
- ❖ for academic and commercial use

➔ **STANDARDIZATION**

AI Specifics:

Means:

- ❖ proprietary datasets, a/o
- ❖ proprietary algorithm strategies, a/o
- ❖ proprietary source code & libraries a/o

Effect:

- \+ proprietary position, e.g. exclusive dataset, as basis to receive funding, investments, exit strategies
- \+ application specific IP possible
- \+ basis to financially leverage competitive advantage
- − potentially limited innovation progress
- − potentially unclear ethical standards

Applied by (not limited to):

- companies that want to ty specific innovation to their business model and keep exclusivity
- startups with need for external investment

Means:

- ❖ access to common datasets & pooling of datasets to increase learning basis, a/o
- ❖ publication of algorithm strategies, a/o
- ❖ publication of source code & libraries, a/o

Effect:

- \+ acceleration of innovation progress
- \+ free flow of information
- \+ open discussion
- \+ foster publications
- − pressure to gain intrinsic R&D, public funding or philanthropic investments

Applied by (not limited to):

- public institutions and research institutes, e.g. MILA Montréal
- companies and institutions that need access to (also specific) datasets or want to accelerate their innovation progress

➔ **ENTREPRENEURIAL AI PIONEERS USE BOTH MODELS IN PARALLEL**

Fig. 8 Balancing proprietary innovation and open innovation (own illustration) while still bridging to comparatively traditionally slow decision taking and reluctant adoption processes of large corporations (Šrámek 2019). Especially when it comes to funding or direct investments, the critical questions of how to deal with public contribution and value capturing have become an important premise and set the pace for where to apply formal and informal protection strategies and how to balance these.

To quote the Silicon Valley-based private American venture capital firm, Andreessen Horowitz (Frank Chen 2019): "When investing in startups, we think about where the pockets are that can make money in the shadow of the giants (i.e., Amazon, Google, Microsoft, and Facebook). These large companies are investing a lot in AI, so startups need to be thoughtful about what will differentiate them in a valley of giants. For instance, when we're looking at a company in the AI space, we look for startups that:

1. Have smart, ambitious teams ready to think outside the box;
2. Have access to a dataset that the giants don't (i.e., partnering with companies who may not want to give Google their business transaction data); and
3. Are not over-rotated on AI. In the computer industry, we've got dozens of billion-dollar companies and a lot of opportunities ahead. AI is not a panacea."

Various large corporations have also begun using AI to complement their core competencies using merger and acquisition to grow and accomplish their AI competence portfolio (Fig. 9). This is because it is especially smaller companies in AI that have a primary focus on using AI for specific purposes or products or within a specific industry sector (e.g., in the pharmaceutical or the automotive sector) (Table 1).

Potential AI-enabled systems are upcoming based on AI technologies that are already starting to affect urban life, with autonomous transportation as the currently most visible AI application (Grosz and Stone 2018). The Stanford One Hundred Year Study on Artificial Intelligence, generally referred to as "AI100," is dedicated

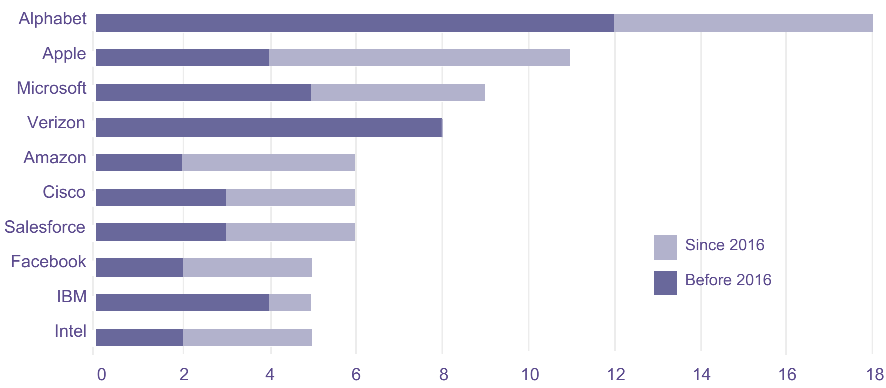

Fig. 9 Number of AI-related companies acquired by top acquiring companies (WIPO 2019a)

Table 1 Companies specialized in AI with AI-related top patents (EconSight 2019)[a]

Ranking	Company	# of AI related top patents	Total # of AI related patents	Total # of patents	% AI related patents
1	Brain Corp.	35	75	87	86.2
2	Heart Flow	30	51	63	81.0
3	Blast Motion	24	28	46	60.9
4	Digital Doors	13	16	18	88.9
5	Megvii	9	146	257	56.8
6	Causam Energy	9	36	56	64.3
7	SenseTime	7	335	415	80.7
8	Mitek Systems	7	18	36	50.0
9	InteraXon	7	8	9	88.9
10	ABBYY Software	6	129	215	60.0
11	Intelligent Technologies Int.	6	21	40	52.5
12	Health Discovery Corporation	6	20	24	83.3
13	Guardant Health	6	13	24	54.2
14	uBiome	5	56	61	91.8
15	MyScript	5	29	30	96.7
16	Preferred Networks	5	27	30	90.0
17	Iteris	5	23	42	54.8
18	Sinoeast Concept	5	20	34	58.8
19	Natera	5	19	33	57.6
20	Veridium	5	11	14	78.6
21	Affectomatics Ltd.	5	10	10	100.0
22	Age Of Learning Inc.	5	8	12	66.7
23	Myskin Inc.	5	6	6	100.0
24	Applied Recognition Inc.	5	5	5	100.0
25	Blanding Hovenweep	5	5	5	100.0
26	Cylance	4	39	50	78.0
27	Knowm	4	30	34	88.2
28	Biodesix Inc	4	23	37	62.2
29	Trust Sience	4	15	15	100.0
30	Qeexo Company	4	12	17	70.6
31	Great Lakes Neurotechnologies Inc	4	9	14	64.3
32	Purepredictive Inc.	4	9	9	100.0
33	VRVis	4	6	10	60.0
34	Arb Labs	4	5	7	71.4
35	Blazent Inc	4	4	6	66.7
36	Biocatch Ltd	3	39	49	79.6

(continued)

Table 1 (continued)

Ranking	Company	# of AI related top patents	Total # of AI related patents	Total # of patents	% AI related patents
37	PCCI	3	19	19	100.0
38	Veracyte	3	14	16	87.5
39	Digital Reasoning Systems Inc.	3	11	12	91.7
40	Interactive Memo-ries Inc.	3	11	12	91.7
41	Linestream Technol-ogies Inc.	3	10	16	62.5
42	Ultrata Llc	3	10	10	100.0
43	Pedstowe Limited	3	8	11	72.7
44	Interos Solutions	3	8	8	100.0
45	Memorial Health Trust Inc.	3	8	8	100.0
46	WHOOP Inc	3	5	7	71.4
47	Solano Labs	3	5	5	100.0
48	Advanced Elemental Technologies	3	4	5	80.0
49	Textwise Company Llc	3	4	5	80.0
50	Z Advanced Computing	3	4	4	100.0

[a]"Top patents" with regard to Ernst and Omland (2011) taking into account citation based relevance

to assessing AI's influences on people, communities, and society, and recently published their first forward-looking assessment on life in 2030: AI, in the long run, might challenge human cognitive jobs while enhancing the benefits of owning intellectual capital (Stone et al. 2016).

Therefore, innovation in AI-based business models combined with value capturing based on formal and informal IP protection strategies retains its relevance. However, this approach is likely to be challenged by the public's appreciation of fairness and equitableness with regard to public goods and commons and the innovator's striving for appropriability.

Acknowledgements As the basis for the AI intellectual property rights and patent data, as well as for some AI technology trend statements, we have relied on data of the just published report of the World Intellectual Property Organization "WIPO Technology Trends 2019: Artificial Intelligence." We have clearly indicated if changes were made to the original content.

We also acknowledge the support given by Ms. Karin Klöti, consultant at BGW AG, St. Gallen.

Glossary[4]

Banking and finance Machine learning is already deeply integrated into many aspects of financial systems, from the approval of loans to the management of assets and the assessment of risks. Automated trading systems involve the use of complex AI algorithms to make extremely fast trading decisions. Modern fraud detection systems actively learn new potential security threats. AI is predicted to have an impact on financial customer services in the future, with specialized chatbots and voice assistants and recommendation systems for financial products and for improving safety by exploiting advances in biometric systems.

Computer vision An interdisciplinary field that deals with how computers see and understand digital images and videos. Computer vision spans all tasks performed by biological vision systems, including "seeing" or sensing a visual stimulus, understanding what is being seen, and extracting complex information into a form that can be used in other processes.

Computer-implemented inventions (CII) Computer-implemented inventions are treated differently by patent offices in different regions of the world. In Europe, Article 52 of the European Patent Convention (EPC) excludes computer programs "as such" from patent protection. This exclusion does not mean that all inventions involving software are excluded from patenting; what it does mean is that tighter scrutiny of the technical character of these inventions is required. Over the years, the case law of the EPO boards of appeal has clarified the implications of Article 52 EPC, establishing a stable and predictable framework for the patentability of computer-implemented inventions. Like all other inventions, in order to be patentable, computer-implemented inventions must meet the fundamental legal requirements of novelty, inventive step, and industrial application. In addition, it must be established that they have a technical character that distinguishes them from computer programs "as such." In other words, they must solve a technical problem in a novel and non-obvious manner. The normal physical effects of the execution of a program, e.g., electrical currents, are not in themselves sufficient to lend a computer program technical character, and a further technical effect is needed. The further technical effect may result, for example, from the control of an industrial process or the working of a piece of machinery, or from the internal functioning of the computer itself (e.g., memory organization, program execution control) under the influence of the computer program. The EPC thus enables the EPO to grant patents for inventions in many fields of technology in which computer programs make a technical contribution. Such fields include medical devices, the automotive sector, aerospace, industrial control, communication/media technology, including automated natural language translation, voice recognition and video compression, and also the computer/processor itself.

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[4]Based on extracts from EPO (2017), WIPO (2004, 2019): selected AI categories and terms, and WIPO (2019b).

Copyright Copyright laws grant authors, artists, and other creators protection for their literary and artistic creations, generally referred to as "works." A closely associated field is "related rights" or rights related to copyright that encompass rights similar or identical to those of copyright, although sometimes more limited and of shorter duration. The beneficiaries of related rights are (a) performers (such as actors and musicians) in their performances, (b) producers of phonograms (for example, compact discs) in their sound recordings, and (c) broadcasting organizations in their radio and television programs. Works covered by copyright include, but are not limited to, novels, poems, plays, reference works, newspapers, advertisements, computer programs, databases, films, musical compositions, choreography, paintings, drawings, photographs, sculpture, architecture, maps, and technical drawings.

Deep learning A machine learning approach that tries to understand the world in terms of a hierarchy of concepts. Most deep learning models are implemented by increasing the number of layers in a neural network.

Distributed AI Systems consisting of distributed, multiple autonomous learning agents which process independently data and provide partial solutions which are then integrated, through communication nodes connecting the individual agents. Distributed AI systems can by design aim at solving complex learning and decision-making tasks, involving large datasets and requiring high computational power.

Document management and publishing Over the past two decades, AI has been continuously improving automatic data extraction, structuring, and conversion of documents (including automatic translation). Improved document clustering and advanced data analytics are expected to better exploit the huge volume of documents that exist. AI-powered document management systems could also enhance security and protect customer data.

Expert system A computer system that solves complex problems within a specialized domain, usually requiring a high level of human intelligence and expertise. This expertise is expressed manually by human experts in the form of a set of rules which are simple logical tests.

Fuzzy logic A decision-making approach which is not based on the usual "true or false" assessment, but rather on "degrees of truth" (where the "true" value ranges between completely true and completely false). Fuzzy logic relies on the principle that people make decisions based on imprecise and non-numerical information.

Industrial Design Right Refers to the ornamental or aesthetic aspects of an article. A design may consist of three-dimensional features, such as the shape or surface of an article, or two-dimensional features, such as patterns, lines, or color. Industrial designs are applied to a wide variety of industrial products and handicrafts: from technical and medical instruments to watches, jewelry, and other luxury items; from house wares and electrical appliances to vehicles and architectural structures; from textile designs to leisure goods. To be protected under most national laws, an industrial design must be new or original and nonfunctional. This means that an industrial design is primarily of an aesthetic nature, and any technical features of the article to which it is applied are not protected by the design registration. However, those features could be protected by a patent.

Industry and manufacturing AI is likely to have major impact on industry and manufacturing. Predictive maintenance is expected to limit costs related to unplanned downtime and malfunction. AI algorithms should also help companies to cope with the increasing complexity of products, engineering processes, and quality regulations. Improved robots are expected to handle more cognitive tasks and make autonomous decisions. Generative design systems are able to quickly generate, explore, and optimize design alternatives from a set of high-level design goals. Continuous monitoring of the market by AI tools could help proactively to optimize staffing, inventory, energy consumption, and the supply of raw materials.

Knowledge representation and reasoning The field dedicated to representing information about the world usable by a computer to solve complex tasks. These representations are usually based on the way humans represent knowledge, reason (for instance, through rules and building relations of sets and subsets), and solve problems.

Life and medical sciences Automatic diagnostic systems are a very promising application of new machine learning techniques. Recent results have shown that it is possible to surpass human expert accuracy for several narrow tasks, such as detection of melanoma or risks of atherosclerosis in arteries. Drug personalization is also frequently cited as a key marker of progress driven by AI. The availability of large amounts of clinical data mean AI is predicted to improve drug discovery and reduce development costs by helping select the most promising hypotheses and focus on more targeted research.

Logic programming Uses facts and rules to make decisions, without specifying additional intermediary steps, in order to achieve a particular goal.

Machine learning An AI process that uses algorithms and statistical models to allow computers to make decisions without having to explicitly program it to perform the task. Machine learning algorithms build a model on sample data used as training data in order to identify and extract patterns from data and therefore acquire their own knowledge. A typical example is a program that identifies and filters spam email.

Natural language processing Use of algorithms to analyze human (natural) language data so that computers can understand what humans have written or said and further interact with them.

Neural network A learning process inspired by the neural structures of the brain. The network is a connected framework of many functions (neurons) working together to process multiple data inputs. The network is generally organized in successive layers of functions, each layer using the output of the previous one as an input.

Object tracking The process of locating one or more moving objects over time in a video.

Ontology engineering A set of tasks related to the methodologies for building ontologies, namely the way concepts and their relationship in a particular domain are formally represented.

Patent An exclusive right granted for an invention—a product or process that provides a new way of doing something, or that offers a new technical solution to a problem. A patent provides patent owners with protection for their inventions. Protection is granted for a limited period, generally 20 years.

Planning/scheduling The realization of strategies or action sequences for execution by intelligent agents, such as autonomous robots and unmanned vehicles.

Predictive analytics The process of making predictions about future or otherwise unknown events using a variety of statistical techniques to analyze current and historical facts.

Probabilistic reasoning An AI approach which combines deductive logic and probability theory to model logical relations under uncertainty in data.

Robotics The design, construction, and operation of machines able to follow step-by-step instructions or perform complex actions automatically and with a certain level of autonomy. Robotics combines hardware with the implementation of AI techniques to perform these tasks. Agents which process independently data and provide partial solutions which are then integrated, through communication nodes connecting the individual agents. Distributed AI systems can by design aim at solving complex learning and decision-making tasks, involving large datasets and requiring high computational power.

Security Cyber-security (spam filtering, intrusion-detection) has benefited from machine learning since the 1990s. Automated surveillance is developing quickly, sometimes in conjunction with smart city technologies. AI techniques such as face detection, behavior, and crowd analysis are mature enough to make surveillance cameras more "active" without the need for human supervision. Predictive policing technology has started to be used in several US states and the UK and AI techniques are also integrated in mass surveillance programs. AI is also considered as a new enabler for a vast range of military requirements, including intelligence, surveillance, reconnaissance, logistics, battlefield planning, weapons systems, and defense/offense decisions.

Speech processing Systems involving analysis of speech signals, including speech recognition, natural language processing, and speech synthesis.

Speech recognition The process of identifying words in spoken language and of translating them into text.

Speech synthesis The artificial production of human speech.

Supervised learning The most widely adopted form of machine learning. In supervised learning, the expected grouping of the information in certain categories (output) is provided to the computer through examples of data (input) which have been manually categorized correctly and form the training dataset. Based on these examples of input–output, the AI system can categorize new, unseen data into the predefined categories.

Telecommunications AI is expected to drive new opportunities in telecoms by helping to improve network performance, thanks to anomaly detection and prediction of service degradations, and also by optimizing customer services.

Trade Secret Any confidential business information which provides an enterprise a competitive edge may be considered a trade secret. Trade secrets encompass manufacturing or industrial secrets and commercial secrets. The unauthorized use of such information by persons other than the holder is regarded as an unfair practice and a violation of the trade secret. Depending on the legal system, the protection of trade secrets forms part of the general concept of protection against unfair competition or is based on specific provisions or case law on the protection of confidential information. The subject matter of trade secrets is usually defined in broad terms and includes sales methods, distribution methods, consumer profiles, advertising strategies, lists of suppliers and clients, and manufacturing processes. While a final determination of what information constitutes a trade secret will depend on the circumstances of each individual case, clearly unfair practices in respect of secret information include industrial or commercial espionage, breach of contract, and breach of confidence.

Trademark A distinctive sign that identifies certain goods or services produced or provided by an individual or a company. Its origin dates back to ancient times when craftsmen reproduced their signatures, or "marks," on their artistic works or products of a functional or practical nature. Over the years, these marks have evolved into today's system of trademark registration and protection. The system helps consumers to identify and purchase a product or service based on whether its specific characteristics and quality—as indicated by its unique trademark—meet their needs.

Transportation Fuzzy logic and other AI approaches have been used in transportation since the 1980s. It is widely predicted that autonomous vehicles will save costs, lower emissions, and enhance road safety and that AI will improve traffic management by reducing traffic jams and make possible crewless cargo ships and fully automated package delivery.

Unsupervised learning A type of machine learning algorithm that finds and analyzes hidden patterns or commonalities in data that has not been labeled or classified. Unlike supervised learning, the system has not been provided with a predefined set of classes, but rather identifies patterns and creates labels/groups in which it classifies the data.

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Digital Absorptive Capacity in Blockchain Start-ups

R. A. Chacón and A. C. Presse

Abstract The aim of this research is providing different audiences such as entrepreneurs, researchers, CEOs, strategic managers, and business owners with the information necessary about absorptive capacity and its relation to firm performance in the context of increasingly digitalized economy. The topic is of relevance as the acquisition of knowledge and its conversion into dynamic capabilities provides enterprises with the possibility to go through digital transition and transform the acquired knowledge into modified business models, innovative products, and upgraded services. Since the first crafting of absorptive capacity theory in the beginning of 1990s, there has been ample research on its application in medium and large companies. The contribution of this study is that it assesses the concept of absorptive capacity and its impact on firm performance in start-ups. The methodological approach involves quantitative data analysis using a survey applied to a sample of 44 blockchain start-ups measuring the following variables: acquisition, assimilation, transformation, and exploitation. We analyzed firm performance through a variety of concepts previously tested in other studies, sales growth, profit growth, growth in market share, and growth in return on capital, and found a positive relationship between AC and firm performance in blockchain start-ups. However, based on our findings, we cannot conclude that blockchain start-ups are more successful *because* of their AC. Therefore, we suggest further examination of items more specific to the demands of an increasingly digital economy.

Keywords Absorptive capacity · Firm performance · Technology · Start-ups · Blockchain · Digital transformation

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1 Introduction

The fourth industrial revolution provides us with ample opportunities for the exploitation and implementation of knowledge created as well as advancing technology and science. This can go from the establishment of new types of business models to providing the bases for the creation of innovative services, products, processes, or knowledge. Are all of these changes incited by innovation? If so, it would be important to point out that innovation is not one process but a series of different processes inside of organizations.

One example of how innovation and technology have impacted people's life is the so-called process of digital transformation (Smith 2008; Soluk 2018). Digital transformation has changed three major aspects of life, which include the generalized use of digital technologies, changes within organizations, and changes in society (Reis et al. 2018). Having millions of people and institutions connected to the Internet along with the use of mobile devices have provided new products and services related to IoT, 3-D printing, nanotechnology, biotechnology, and quantum computing just to mention a few of them. To this list, we should add all innovations supplied and created by the implementation of blockchain, artificial intelligence, as well as all cryptocurrencies.

Through innovation and technology advances, there is a bigger capacity of reaching more customers and making transactions much faster in almost any type of market (David 2001). However, for these innovations to take place, be completed, create value, and finally be traduced into profits, return, and performance (Karimi and Walter 2015; Leiponen and Helfat 2010), it takes a lot of resources, cooperation among different operational areas, as well as continuity. One example of these efforts are the entrepreneurial and intrapreneurial activities. These strategies keep businesses thriving in this increasingly aggressive, competitive, and dynamic marketplace.

The case of start-ups is different from big enterprises (Johnson 2001) as they are structured in a different way which grants them with different advantages allowing them to keep fresh ideas, rapid growth, and flexibility in the case of a radical technological change or disruption (Karimi and Walter 2015). Those differences to name a few of them are agility, less bureaucracy, and versatility in their team structure, for example. These characteristics make start-ups an important part of the economic structure that eventually turns into economic growth, stability, and technological advances.

In this context, some questions that remain partially unanswered are: how are businesses able to cope with the rapid changes in technology? What is the specific case of start-ups? How do they do it? Is it only about the flexibility, fresh ideas, and rapid growth, which helps them stay in the market? Is it the amount of money invested in their new products or services? Or are there any other characteristics or abilities that businesses have to develop in order to go as fast as the technology and receive all the gains of it like better firm performance while creating new products, services, and competitive advantages?

Through this research, the question we will answer is: *Do Start-ups with high levels of absorptive capacity also have high levels of firm performance and how does this compare with start-ups with low levels of absorptive capacity?* The concept of absorptive capacity will be taken as framework of analysis looking forward to measure what are start-ups doing to acquire knowledge and turn it into new business models, ideas, processes, products, or services and how does this reflect on firm performance.

2 Theoretical Framework and Review of Relevant Literature

2.1 The Theoretical Concept of Absorptive Capacity (AC)

The theoretical concept of AC was developed around the 1990s when Wesley M. Cohen and Daniel A. Levinthal from the Johnson Graduate School of Management of Cornell University wrote a document named "Absorptive Capacity: A New Perspective on Learning and Innovation" in which they explain that innovation is a process that includes among many other things investment in knowledge acquisition from outside of an organization or a process. They made an analogy between human beings and organizations by comparing the human cognitive behavioral ability to acquire knowledge and then turn it into something new through a creative process. The comparison is made to point out that a human being, who is in contact with information from different sources outside of it, assimilates the information learning it and using it to produce something else as a result of the cognitive process. The authors of the theory claim that inside of an organization the same happens (Zahra and George 2002).

The organization develops the ability to absorb or bring information from the outside, through a "gatekeeper" (Cohen and Levinthal 1990; Liao et al. 2003) to the inside and through a specific internal process exploits it, which afterward turns into an economic gain. This is a critical component of innovative capabilities (Cohen and Levinthal 1990) and its dissemination along the organization so that the exploited knowledge grows and turns out into beneficial results for the organizations (Wales et al. 2012).

Afterward, the concept was completely redefined by Zahra and George (2002, p. 135) in which they conceptualized AC as "*a set of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organizational capability*."

The concept of AC is useful for gaining and sustaining a competitive advantage especially for the firm to adapt to changing market conditions. The concept is treated as a tool to produce innovations inside of an organization or business and thus the expected result would be a competitive advantage in areas such as marketing, distribution, or production just to mention a few of them. Competitive advantages help businesses survive especially in markets that are driven by a fast pace in technology or in the case of disruptive technologies such as digital technologies.

Since the concept was first brought to light, at the beginning of the 1990s, it has been tested in companies that are considered as big enterprises. However, we decided to test this concept in blockchain start-ups for its importance for the transition to a digital economy but also because these economic entities are clearly going through a technological disruption such as blockchain.

2.2 The Concept of Firm Performance

The concept of firm performance is fundamental for the present research as it is through it that we can measure if a business is financially stable or in which stage of development it is found. Further it is a key indicator of how businesses are evolving and developing (Engelen et al. 2015; Gilbert et al. 2006). The concept has two different paths of thought; the first one states that there is a positive linear relationship between AC and firm performance (Cohen and Levinthal 1990; Leonard-Barton 1995; Tsai 2001; Zahra and George 2002) and the second one conveys that AC diminishes firm performance or is maximized at relatively low levels of AC and is harmful past moderate levels of AC (Wales et al. 2012). Regarding this last point, the literature makes clear that the investment in AC in most of the organizations is really high bringing diminishing returns in the long run which means the organization at some point will stop getting the benefits they used to have even though they keep on investing more and more preventing the business to make profits (Wales et al. 2012).

For firm performance, we decided to take the scale done by Chirico et al. (2011), Kellermanns et al. (2012), Naldi et al. (2007), and Kraus et al. (2012). The four variables are sales growth, profit growth, growth in market share, and growth in return on capital.

2.3 The Concept of Start-up

After 2008 worldwide economic crisis, different parts of the world started their way to recovery through different plans. In the case of Europe, it was on June 25, 2008, when the European Commission (European Commission 2008) created the "Small Business Act" (SBA) which aims to "improve the approach to entrepreneurship in Europe, simplify the regulatory and policy environment for SMEs, and remove the remaining barriers to their development." The main idea behind this was to bring Europe back to growth and create new jobs unleashing Europe's entrepreneurial potential. Through the strategy of "Think Small First" aside from the SBA, the European Commission created another plan called the "Entrepreneurship 2020 Action Plan" (European Commission 2015) in an attempt to encourage future entrepreneurs to develop their business ideas. This strategy has worked positively in different cities of Europe. One clear example is Berlin Start-up Hub (Adams 2016; Holtschke 2018; Scott 2018).

Even though start-ups might seem the same as SMEs, they are not. The definition of the European Start-up Monitor (2016) states they are young companies oriented toward growth that are in search of sustainable and scalable business model. They differ from classic enterprises in terms of innovation and the number of employees (therefore) a start-up has the following characteristics:

- Businesses younger than 10 years.
- They feature (highly) innovative technologies and/or business models.
- They (strive) for significant employee and/or sales growth.

2.4 What Is Blockchain?

Blockchain is part of what we call digital transformation, as it is a technology connected to the digital platforms that replace traditional middlemen or middle institutions. Since Bitcoin was invented by Satoshi Nakamoto in 2008 (Nakamoto 2008) as a peer-to-peer electronic cash, many technological changes have happened including a new era in the monetary history and payment methods around the world. Bitcoin has also impacted the use and evolution of blockchain as a technology that is needed for the mining of cryptocurrencies but that is also used in different industries (Tapscott 2018).

Today, there are around 732 different types of cryptocurrencies that were born after Bitcoin—one that has gained more value and adopters in the market according to coinmarketcap.com. On the other hand, blockchain is said to be the backbone where Bitcoin was first running. About this specific aspect of Bitcoin, Satoshi Nakamoto did never address this concept in the paper in which he explains the base of Bitcoin and he certainly never calls this new technology as "blockchain." In reality, he writes about a software design that uses several existing technologies, which allowed him to create a purely "peer-to-peer" version of electronic cash (Ammous 2018).

After blockchain was first used as the software in which Bitcoin can be used, the tech community has been looking for different use cases attempting to create new business models around it. The definition of Lemieux (2016, p. 118) states that blockchain is

> a distributed transaction database in which different computers-called nodes-cooperate as a system to store sequences of bits that are encrypted as a single unit or block and then chained together.

Some of the characteristics of this technology are *transparency* because all transactions can be seen by all the users, yet keeping the privacy of its users; *reliability* because there is no chance that a single transaction can be changed once it was accomplished (immutable information); *accountability* because the transactions are shared simultaneously among all its users which can reconcile the

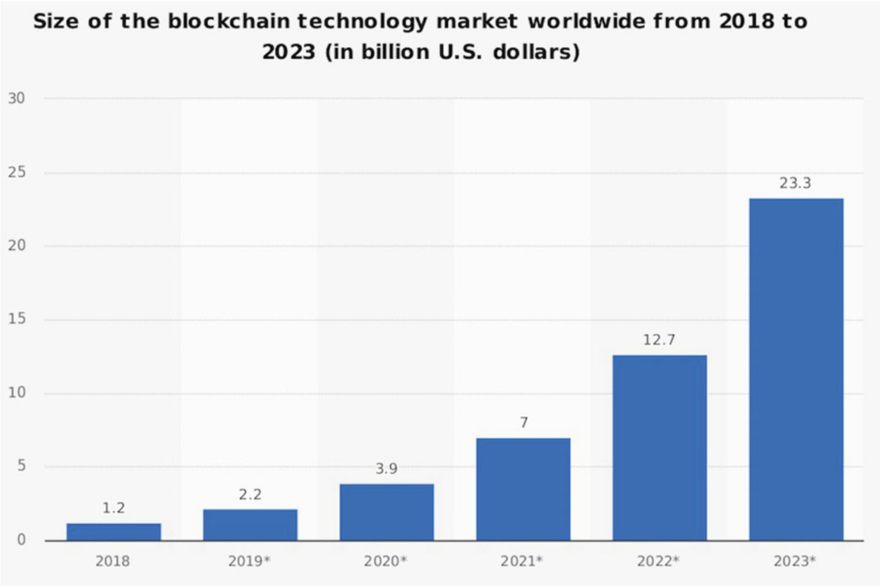

Fig. 1 Blockchain actual or projected market size worldwide 2018–2023 (billion U.S. dollars). Source Statista

information continuously as this is public among the members of the network chosen; *decentralization* because the data is not stored in a single database, rather it is like a public "spreadsheet" shared by all the users; *autonomy* because transactions will clear if valid, and will not clear if they are not valid peer-to-peer without intermediaries. At last, it is important to point out that one of the undeniable truths about blockchain is that network processes work first on the basis of trust and consensus. When two members of a blockchain interact, they announce the transaction to the whole network members (nodes) who record the transaction into a block (Ammous 2018).

Because of all these benefits, blockchain technology has been growing itself as a market-opportunity investment based on future development rather than on present profits. Below we can see a figure of the size of the market growth in blockchain technology for 2021, which clearly shows the market potential (Fig. 1).

3 Methodology

For the research design, we decided to use means, standard deviations, and percentages (Black 1999; Cheng-Few et al. 2000; Firestone 1987) on account of being a reliable falsifiable, generalizable, and replicable research method (Adcock 2001).

Table 1 Hypotheses

H1	Acquisition is positively related to firm performance
H2	Assimilation is positively related to firm performance
H3	Transformation is positively related to firm performance
H4	Exploitation is positively related to firm performance

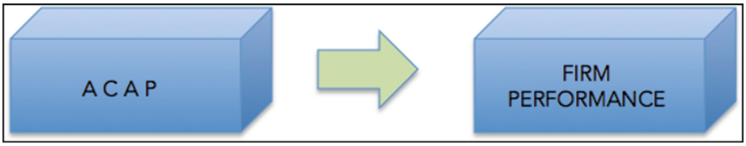

Fig. 2 Tested variables model

Following this technique, when data was collected, the results were counted, classified, and analyzed with the help of a statistical model and software.

The purpose of our methodological section was to measure through a survey if start-ups are using AC within their internal processes and in what level. Therefore, we measured the presence of AC in relation to the concept of firm performance. After applying an online survey (Andrews et al. 2003), we divided the data into two groups utilizing an approach of "between experimental design" (Campbell and Stanley 1963). The division of the groups was according to the means of firm performance.

3.1 Objectives

The objectives of the present research were as follows:

- To find out if start-ups utilize AC within their internal processes to achieve innovation.
- To find out if the start-ups that use AC are being more successful than the ones that do not.

In order to answer the research question, there are four proposed hypotheses (Table 1).

According to the research questions and the hypotheses, below we can visualize the variables that were tested (Fig. 2).

3.2 The Survey

The web-based survey (Courper 2000) contained different types of questions that can be revised in Appendix (Hinkin 1998). It was elaborated after the literature

Table 2 Likert scale

1	Strongly disagree
2	Disagree
3	Neither agree nor disagree
4	Agree
5	Strongly agree

Table 3 List of variables tested

Type of variable	Variable tested (nominal or ordinal)	Source of variables
Control variable questions	Size of firm; market segment; year of creation; gender; age; education level	Gundry and Welsch (2001), Hernández-Perlines et al. (2017)
Main variable questions	Acquisition; assimilation; transformation; exploitation (absorptive capacity) and sales growth, profit growth, growth in market share, and growth in return on capital (firm performance)	Flatten et al. (2011), Cohen and Levinthal (1990), Wiklund and Shepherd (2005), Chirico et al. (2011), Kellermanns et al. (2012), Naldi et al. (2007), Kraus et al. (2012)
Filter questions	Time of business foundation	Kollman et al. (2016)

review was conducted, and it was designed according to two different scales. The first scale related to AC (Flatten et al. 2011). The second scale was used to measure firm performance (Chirico et al. 2011; Kellermanns et al. 2012; Naldi et al. 2007; Kraus et al. 2012). The methodology we used is based on four independent variables, acquisition, assimilation, transformation, and exploitation, as well as one dependent variable: firm performance. The questions were close ended and the participants answered choosing specific aspects which were based on a five-point Likert scale (Jamieson 2004; Masters 1974) which was very useful for the measurement of opinions (Field et al. 2014) (Table 2).

The survey was sent out for the first time on May 26, 2018, as a way to make a test, and after receiving some comments from the academic community and from the first respondents, we decided to make adjustments and then send the survey out again in a different platform (Hunt et al. 1982). The first time it was sent out in Survey Monkey Platform and the second time it was sent out through www.sosci.de. Afterward, it was distributed by email, social media, and meet-ups, as well as in a Congress related to blockchain start-ups called *Blockchain Expo Amsterdam 2018* that took place at the RAI Amsterdam on June 27 and 28, 2018.

The three different sections in the survey are described in detail in Table 3 for a better overview of the conceptualization (Field et al. 2014).

3.3 First Section: Control and Filter Questions

Filter questions and control variable questions (Hernández-Perlines et al. 2017) were used according to the authors mentioned. The first filter questions were related to the use of blockchain technology in start-ups as this specific group was our target sample. We considered part of our population all start-ups that were using blockchain technology but also the ones that are planning to use the technology in the future. The reason is that blockchain has not fully been developed so we believe that some businesses are using the technology that is available in the market but at the same time they are advancing and acquiring new knowledge to transform it into new products, services, or processes. This transition is important because at this stage a business is looking forward to actively advance in its innovation processes and keep on advancing on the acquisition of the technology.

3.4 Second Section: Independent Variable, AC

In this section, the questions measured the independent variables of AC: acquisition, assimilation, transformation, and exploitation through the scale that was proposed by Cohen and Levinthal (1990) and was validated by Flatten et al. (2011).

3.5 Third Section: Dependent Variable, Firm Performance

In this section of the survey, the variables measured firm performance using a scale developed by Wiklund and Shepherd (2005), Chirico et al. (2011), Kellermanns et al. (2012), Naldi et al. (2007), and Kraus et al. (2012) which include four variables such as sales growth, profit growth, growth in market share, and growth in return on capital.

3.6 The Sample

The sample in which we applied the survey was a group of “blockchain start-ups” as a subset of the population “start-ups” taking into consideration the three main characteristics of them (Kollman et al. 2016):

- Businesses opened less than 10 years ago
- Businesses using innovative technologies (such as online services, the usage of apps)
- Significant sales growth in the last 5 years

Table 4 Summary of standard deviation and variance (SPSS)

	N	Mean	Std. deviation	Variance
Firm performance	44	3.4773	0.66433	0.441
Acquisition	44	4.2575	0.44223	0.196
Assimilation	44	4.0057	0.65033	0.423
Transformation	44	4.1591	0.61496	0.378
Exploitation	44	4.3336	0.63900	0.408
Valid *N* (listwise)	44			

3.7 Data Management and Statistics

The survey was answered 54 times and only 44 were complete and complied with all necessary characteristics of the target sample. Eight responses were not part of the sample, and we took them out of the analysis and two of them were missing control data information; therefore, we also took them out (Hammersley 1987). The data was evaluated with Excel and with SPSS in which different types of analysis were made. First, demographics information was analyzed using percentages and frequencies. Second, a descriptive statistics report is presented that includes standard deviation, means, and variance for each variable. Third, a histogram and frequencies are presented for each one of the five variables. Fourth, percentages are presented for each variable and its dimensions according to two major groups identified. Fifth, variables were classified according to the means in two groups and used to analyze each one of the hypothesis and subhypothesis tested. Below we present the summary of the values of the dependent and independent variables.

In Table 4 shows a summary of the general information of the distribution of our dependent variable (firm performance) and the four independent variables (acquisition, assimilation, transformation, and exploitation). According to the respondents, we can see that the means of the four independent variables and the dependent variable are in a range between 3.47 and 4.33 in the Likert scale. This explains that most of the respondents are found between "agree" and "strongly agree." The standard deviation is less than 1 which defines that at least 68% of the data or more falls in a range of less than 1 standard deviation from the mean. Most of the respondents are gathered around the mean and the data is not spread or is highly concentrated around the mean. The deviation of this data is standard and expected.

3.8 Frequencies: Firm Performance

Firm performance measured in respondents how they evaluate different financial variables in their start-up against the ones of their competitors. Below we can see the frequencies table and histogram which show that most of the answers fall under the category "neither agree nor disagree" and a little bit further in "agree" (Table 5).

Table 5 Firm performance (SPSS)

Valid	Frequency	Percent	Valid percent	Cumulative percent
2.00	1	2.3	2.3	2.3
2.25	1	2.3	2.3	4.5
2.75	2	4.5	4.5	9.1
3.00	16	36.4	36.4	45.5
3.25	1	2.3	2.3	47.7
3.50	5	11.4	11.4	59.1
3.75	4	9.1	9.1	68.2
4.00	8	18.2	18.2	86.4
4.25	3	6.8	6.8	93.2
4.75	1	2.3	2.3	95.5
5.00	2	4.5	4.5	100.0
Total	44	100.0	100.0	

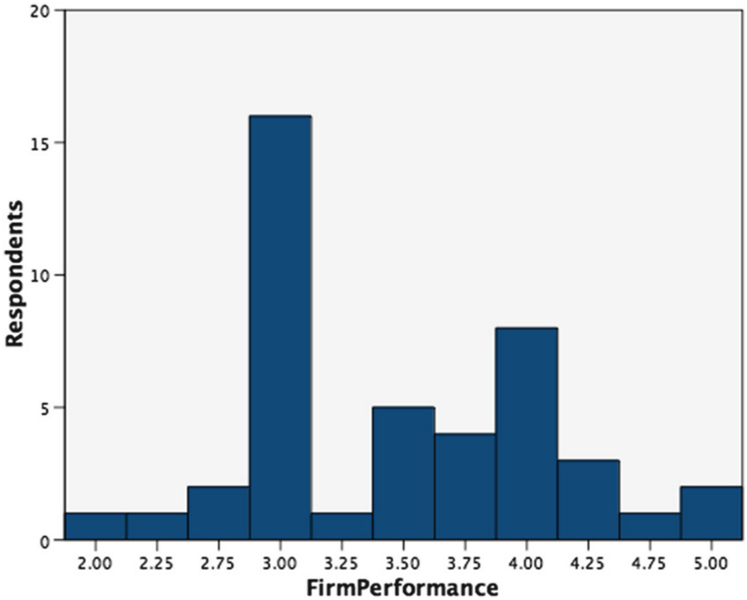

Fig. 3 Histogram firm performance (SPSS)

In the frequencies table, we can see that the sample answered unequally and we can easily spot two different peaks. The first one is in the "neither agree nor disagree" (36%) and the second peak around the "agree" section (18%). The histogram below shows it more clearly (Fig. 3).

Table 6 Acquisition (SPSS)

Valid	Frequency	Percent	Valid percent	Cumulative percent
3.33	1	2.3	2.3	2.3
3.67	5	11.4	11.4	13.6
4.00	16	36.4	36.4	50.0
4.33	10	22.7	22.7	72.7
4.67	5	11.4	11.4	84.1
5.00	7	15.9	15.9	100.0
Total	44	100.0	100.0	

Table 7 Assimilation (SPSS)

Valid	Frequency	Percent	Valid percent	Cumulative percent
2.00	1	2.3	2.3	2.3
2.50	1	2.3	2.3	4.5
2.75	1	2.3	2.3	6.8
3.00	1	2.3	2.3	9.1
3.25	1	2.3	2.3	11.4
3.50	5	11.4	11.4	22.7
3.75	5	11.4	11.4	34.1
4.00	10	22.7	22.7	56.8
4.25	7	15.9	15.9	72.7
4.50	4	9.1	9.1	81.8
4.75	5	11.4	11.4	93.2
5.00	3	6.8	6.8	100.0
Total	44	100.0	100.0	

3.8.1 Acquisition

The first of the four independent variables, acquisition, measured three different aspects of how start-ups acquire information about their industry and the question states, "*to what extent do your business uses external sources to obtain information?*"

In the frequencies table, we can see that most (58%) of the respondents fall in 4.00 and 4.33 of agreement, which means they "agree" and "strongly agree" with the statements presented. This explains that start-ups are very active in using external sources to obtain information about their industry (Table 6).

3.8.2 Assimilation

The second of the four independent variables, assimilation, measured in respondents "*to what extent do they agree or disagree about the communication structure*" in their start-up which included how much information about their industry is in the

Table 8 Transformation (SPSS)

Valid	Frequency	Percent	Valid percent	Cumulative percent
2.25	1	2.3	2.3	2.3
3.00	1	2.3	2.3	4.5
3.25	1	2.3	2.3	6.8
3.50	5	11.4	11.4	18.2
3.75	5	11.4	11.4	29.5
4.00	10	22.7	22.7	52.3
4.25	3	6.8	6.8	59.1
4.50	7	15.9	15.9	75.0
4.75	4	9.1	9.1	84.1
5.00	7	15.9	15.9	100.0
Total	44	100.0	100.0	

environment and how much discussion about the new information acquired is encouraged inside of their start-up.

In the frequencies table, we can see that more than 90% of the answers fall under options "agree" and "strongly agree," which means that less than 10% of the respondents fall to the left of the distribution. This signifies that there is plenty of information within these start-ups about their industry, and discussion about these topics is highly encouraged (Table 7).

3.8.3 Transformation

The third of the four independent variables, transformation, measured in respondents "*to what extent do they agree or disagree about the knowledge processing*" within their start-up which included how much ability do the employees have to structure, acquire, and apply new knowledge in their practical work and if this knowledge is linked to existing or previous knowledge.

In the frequencies table, we can see that more than 90% of the respondents "agree" or "strongly agree" with the statements. This explains that within these start-ups people constantly practice and develop their abilities to acquire, structure, and apply new knowledge in their practical work (Table 8).

3.8.4 Exploitation

The fourth independent variable, exploitation, measured in respondents "*to what extent do they agree or disagree about the commercial exploitation of new knowledge*" within their start-up which included how much development of prototypes is supported as well as to what extent does their start-up reconsiders or adapts to new technologies.

Table 9 Exploitation (SPSS)

Valid	Frequency	Percent	Valid percent	Cumulative percent
2.00	1	2.3	2.3	2.3
3.00	1	2.3	2.3	4.5
3.33	1	2.3	2.3	6.8
3.67	5	11.4	11.4	18.2
4.00	8	18.2	18.2	36.4
4.33	8	18.2	18.2	54.5
4.67	8	18.2	18.2	72.7
5.00	12	27.3	27.3	100.0
Total	44	100.0	100.0	

Table 10 Level of AC: firm performance

No.	Variable/groups	Firm performance high AC[a] (%)	Firm performance low AC[b] (%)
1	Average annual sales in the last year	93	7
2	Growth in market share in the last year	93	7
3	Profit growth in the last year	93	7
4	Growth in return on capital	98	2

[a]Group 1 Likert scale range 3–5
[b]Group 2 Likert scale 1–2

In the frequencies table, we can see that 81.9% fall under the categories "agree" and "strongly agree" which shows that start-ups are really active in their exploitation of knowledge as well as in the consideration of new technologies (Table 9).

In a general perspective, our data was not highly spread in terms of standard deviation which means that at least 68% of the data or more falls in the range of less than 1 standard deviation from the mean. There are specifications we must make around this topic.

1. In firm performance, the distribution did not gather effectively around the mean but falls under the category of "neither agree nor disagree" which is a neutral point. If the participants chose a neutral point it can be for at least two reasons: (1) they do not have enough information about their own start-up or (2) they do not have enough information about their competitors. In either case, this was the answer of 36% of the participants.
2. For the other variables, most of the data is distributed to the right of the scale. In the case of the variable acquisition, more than 58% of respondents "agree" and "strongly agree" with the statements. For the variable assimilation, it is more than 90%; for transformation, it is more than 90%; and finally for exploitation, it is more than 81%.

3.9 Level of Absorptive Capacity. Firm Performance

In this analysis, we classified the different dimensions of each of the questions into two groups: Group 1 with high levels of absorptive capacity (3–5 Likert scale) and Group 2 (1–2 Likert scale) with low levels of absorptive capacity (Table 10).

The results of the variable financial performance are: Group 1 with a high level of AC got 93–98% of the respondents in contrast to Group 2 with a low level of AC that got only 2–7%.

Some of the conclusions that can be observed about levels of AC in blockchain start-ups through this group analysis are:

1. The results of the variable financial performance explain us that start-ups believe they are performing either the same than their competitors or better than them.
2. Acquisition of external information within their industry and beyond their industry is highly encouraged.
3. Assimilation of information through a diversity of activities related to cross-departmental communication of the acquired information such as problem solving and flow and interchange of developments is communicated across different departments (e.g., meetings and informal discussions).
4. Transformation of knowledge processing within start-ups is high and it can be seen in different ways such as knowledge collection, knowledge preparation, knowledge processing, and knowledge application in practical work and tasks.
5. Commercial exploitation within start-ups is high and this can be seen in development of prototypes, technological reconsideration for new knowledge, as well as the adoption of new technologies.

3.10 Means: Acquisition, Assimilation, Transformation, and Exploitation Versus Firm Performance

The following analysis was performed first by finding the mean of each one of the variables and then making two groups. Group 1 for the highest mean and Group 2 for the lowest mean (Table 11).

Table 11 Summary of means

Variables/groups	Group 1[a]	Group 2[b]
Firm performance	4.3	2.9
Acquisition	5.0	3.8
Assimilation	4.7	3.1
Transformation	4.9	3.6
Exploitation	5.0	3.7

[a]Group 1 Likert scale range 3–5
[b]Group 2 Likert scale 1–2

According to the comparison of the means in which we divided each one of the variables in two groups, Group 1 high AC and Group 2 low AC, and confronted each one of the independent variables to the different aspects of the dependent variable, we found different conclusions. First, each one of the independent variables of absorptive capacity (acquisition, assimilation, transformation, and exploitation) is directly related to firm performance, which is our dependent variable.

Second, in relation to the different hypotheses presented and after revising each one of the four hypotheses and their subhypothesis, we can conclude that all of them were accepted as all of the means behave in a direct form toward the dependent variable which is firm performance in both Group 1 and Group 2. Therefore, the answers to the research question "*Do Start-ups with high levels of Absorptive Capacity also have high levels of Firm Performance and how does this compare with Start-ups with low levels of Absorptive Capacity?*" are as follows:

- Start-ups with high levels of AC also show high levels of firm performance.
- Start-ups with lower levels of AC also show lower levels of firm performance.

Even though the above statements confirm the type of the relationship that exists between the two variables, we cannot conclude that they have a causal relation. In reality, yes, there is a clear relationship but future affirmations related to firm performance should be further investigated.

3.11 Research Question and Hypotheses Validation

With the means previously compared against the dependent variable, we were able to make the analysis of the hypothesis as follows:

H1 Acquisition is positively related to firm performance

- $H1_a$ Ac is directly related to annual sales growth because when the level of acquisition is high, the level of annual sales growth is also high. As well, when the level of acquisition diminishes, the level of annual sales growth also diminishes.
- $H1_b$ Ac is directly related to growth in market share because when the level of acquisition is high, the level of growth in market share is also high. As well, when the level of acquisition diminishes, the growth in market share also diminishes.
- $H1_c$ Ac is directly related to profit growth because when the level of acquisition is high, the level of profit growth is also high. As well, when the level of acquisition diminishes, the level of profit growth also diminishes.
- $H1_d$ Ac is directly related to growth in return on capital because when the level of acquisition is high, the level of growth in return on capital is also high. As well, when the level of acquisition diminishes, the level of growth in return on capital also diminishes.

H2 Assimilation is positively related to firm performance

- $H2_a$ As is directly related to annual sales growth because when the level of assimilation is high, the level of annual sales growth is also high. As well, when the level of assimilation diminishes, the level of annual sales growth also diminishes.
- $H2_b$ As is directly related to growth in market share because when the level of assimilation is high, the level of growth in market share is also high. As well, when the level of assimilation diminishes, the growth in market share also diminishes.
- $H2_c$ As is directly related to profit growth because when the level of assimilation is high, the level of profit growth is also high. As well, when the level of assimilation diminishes, the level of profit growth also diminishes.
- $H2_d$ As is directly related to growth in return on capital because when the level of assimilation is high, the level of growth in return on capital is also high. As well, when the level of assimilation is lower, the level of growth in return on capital also diminishes.

H3 Transformation is positively related to firm performance

- $H3_a$ Tr is directly related to annual sales growth because when the level of transformation is high, the level of annual sales growth is also high. As well, when the level of transformation diminishes, the level of annual sales growth also diminishes.
- $H3_b$ Tr is directly related to growth in market share because when the level of transformation is high, the level of growth in market share is also high. As well, when the level of transformation diminishes, the growth in market share also diminishes.
- $H3_c$ Tr is directly related to profit growth because when the level of transformation is high, the level of profit growth is also high. As well, when the level of transformation diminishes, the level of profit growth also diminishes.
- $H3_d$ Tr is directly related to growth in return on capital because when the level of transformation is high, the level of growth in return on capital is also high. As well, when the level of transformation is low, the level of growth in return on capital also diminishes.

H4 Exploitation is positively related to firm performance

- $H4_a$ Ex is directly related to annual sales growth because when the level of exploitation is high, the level of annual sales growth is also high. As well, when the level of exploitation diminishes, the level of annual sales growth also diminishes.
- $H4_b$ Ex is directly related to growth in market share because when the level of exploitation is high, the level of growth in market share is also high. As well, when the level of exploitation diminishes, the growth in market share also diminishes.

- $H4_c$ Ex is directly related to profit growth because when the level of exploitation is high, the level of profit growth is also high. As well, when the level of exploitation diminishes, the level of profit growth also diminishes.
- $H4_d$ Ex is directly related to growth in return on capital because when the level of exploitation is high, the level of growth in return on capital is also high. As well, when the level of exploitation diminishes, the level of growth in return on capital also diminishes.

After revising each one of the four hypotheses including their subhypothesis, we can conclude that all of them were accepted as all of the means behave in a direct form toward firm performance in both Group 1 (high levels of AC) and Group 2 (low levels of AC).

4 Conclusion

This chapter is analyzing the relationship between absorptive capacity and firm performance in blockchain start-ups. It provides a better understanding of how AC works within start-ups and its impact on firm performance. Our results suggest that start-ups with high levels of AC display higher levels of firm performance than start-ups with lower levels of AC. Absorptive capacity comprises of four activities: acquisition, assimilation, transformation, and exploitation. We analyzed four variables of firm performance: annual sales growth, growth in market share, profit growth, and growth in return on capital. All four aspects of AC are positively related to the four firm performance indicators. Our findings have implications for start-ups operations.

In relation to the variables of AC specifically related to the management of information and its conversion into new products and services, the findings are:

1. Blockchain start-ups are very active in using external sources of information about their industry.
2. The information they acquire is used and communicated effectively.
3. Once the information has been communicated, the employees are highly encouraged to constantly use and develop their abilities to structure and apply new knowledge in their practical work.
4. The commercial exploitation of new knowledge is actively promoted through the use of prototypes and inclusion of new technologies into their processes.

Implementing processes that facilitate these activities in start-ups can improve their performance. The transition of enterprises in a digital economy yields many opportunities for research. Improving the tools and processes of this transition can make it easier and potentially more profitable for start-ups to transform their business models. Therefore, the development of a digital absorptive capacity theory is suggested as it can be a useful tool not only for start-ups in the process of completing their digital transformation and enhancing their digital strategy but also for businesses that have not been able to start this process yet.

Appendix

TECHNOLOGY USAGE
Is your business using a highly innovative technology such as blockchain?

a) Yes
b) No
c) Not yet but planning to in the future

ACQUISITION OF INFORMATION WITHIN YOUR BUSINESS
Please specify to what extent your business uses external sources to obtain information. Choose on a scale of 1-5, where 1 means strongly disagree and 5 means strongly agree

1. The search of relevant information concerning our industry is every-day business in our industry
2. Our management motivates the employees to use information sources within our industry
3. Our management expects that the employees deal with information beyond our industry

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ASSIMILATION OF INFORMATION WITHIN YOUR BUSINESS
Please rate to what extent the following statements fit the communication structure in your business.

1. In our company ideas and concepts are communicated cross-departmental
2. Our management emphasizes cross-departmental support to solve problems
3. In our company there is a quick information flow, e.g., if a business unit obtains important information it communicates this information promptly to all other business units or departments
4. Our management demands periodical cross-departmental meetings to interchange new developments, problems and achievements

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TRANSFORMATION OF INFORMATION WITHIN YOUR BUSINESS
Please specify to what extent the following statements fit the knowledge processing in your business.

1. Our employees have the ability to structure and to use collected knowledge
2. Our employees are used to absorb new knowledge as well as to prepare it for further purposes and to make it available
3. Our employees successfully link existing knowledge with new insights
4. Our employees are able to apply new knowledge in their practical work

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EXPLOITATION OF INFORMATION WITHIN YOUR BUSINESS
Please specify to what extent the following statements fit the commercial exploitation of new knowledge in your business.

1. Our management supports the development of prototypes
2. Our company regularly reconsiders technologies and adapts them accordant to new knowledge
3. Our company has the ability to work more effective by adopting new technologies

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FINANCIAL PERFORMANCE OF YOUR BUSINESS
Compare the following financial variables of your firm in relation to your competitors.
Scale 1-5, where 1 means much less than competitors and 5 means much more than competitors

1. Average annual sales growth in the last year
2. Growth of market share in the last year
3. Profit growth in the last year
4. Growth of return on capital

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Entrepreneurship in a New Digital Industry: The Emergence and Growth of Mobile Health

Lien Denoo and Helena Yli-Renko

Abstract Digital technologies have changed the nature of entrepreneurship, leading to new types of opportunities, processes, and challenges, as well as to the emergence of new digital industries. In this chapter, we examine the origins, evolution, and structure of the mobile health industry since its emergence around 2005. Using data of 193 young mobile health ventures, we discuss the rapid growth and maturing of the industry, as well as the importance of interorganizational relationships and ecosystem partners. We present an interdisciplinary future research agenda focused on entrepreneurship in emerging digital industries, structured around research themes of business model evolution, ecosystem and alliances, and innovation and data security. This chapter contributes to the understanding of industry emergence, in particular the co-evolution of new ventures and a novel digital industry.

Keywords Entrepreneurship · Mobile health · Digital · Alliances · Innovation

1 Introduction

Digital technologies have changed the nature of entrepreneurship, giving rise to new types of business opportunities and reshaping the processes and resources used to pursue those opportunities (Giones and Brem 2017). Digitalization has led to new business models in established industries, enabling innovation and disruption (Weinelt 2015)—witness Netflix in entertainment or Amazon in retail. Beyond the restructuring of existing industries and businesses, digitalization has also led to the

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birth of novel industries at the intersections of traditional sectors and digital technologies—examples include gaming, ridesharing, and FinTech. However, little is still known about how such new digital industries emerge and develop.

In this chapter, we take a deep dive into the mobile health, or mHealth, industry and examine its origins, evolution, and structure. We discuss the unique features of mHealth as an example of a newly emerged digital industry and present a set of interdisciplinary research opportunities for scholars interested in digital entrepreneurship.

But first, what exactly do we mean by mHealth? mHealth refers to the use of mobile phones for health services and information. Istepanian et al. (2006) define it as "emerging mobile communications and network technologies for healthcare" (p. 3). mHealth is considered narrower than "e-health," which incorporates the use of any electronic devices and systems, whereas mHealth only considers mobile phone applications. mHealth is also distinct from "telemedicine," which uses more traditional desktop platforms (Istepanian et al. 2006). Examples of mHealth applications, products, and services are weight loss and fitness apps for phones; electronic medication prescribing tools that can send prescriptions directly from a physician to a pharmacy; secure messaging systems between patients, doctors, and hospitals; fall detection sensors that send signals to smartphones; medical implants that track certain conditions and send information to doctors; and blood pressure and glucose monitors for smartphones. The mHealth industry thus includes both "digital entrepreneurs" and "digital technology entrepreneurs," as defined by Giones and Brem (2017). Digital entrepreneurs use digital technologies as inputs into providing a service (as in a fitness app for example), whereas for digital technology entrepreneurs, the technology/digital artifact is the actual product (as in a medical implant for example).

The mHealth industry started emerging around 2004–2005 and by 2017 had reached US$26 billion in sales (Jahns 2017). The years in between marked a period of early industry evolution characterized by a search for viable business models as various players entering the industry tried to figure out how value creation and capture would occur (Economist 2016). In this chapter, we provide a descriptive analysis of the industry's emergence and growth, specifically focusing on entrepreneurship within the industry. We draw on a unique longitudinal database of 193 mHealth ventures, tracked from 2005 to 2014, to shed light on the birth of the industry and the trends that have taken place within it.

This chapter will contribute to our understanding of industry emergence and in particular to our understanding of the co-evolution of new ventures and a novel digital industry, responding to calls from Autio et al. (2018) and Spigel and Harrison (2018) for more research on the emergence of entrepreneurial ecosystems. In so doing, we offer insights for researchers, entrepreneurs, and policy makers. We start by introducing the drivers of the emergence of mHealth and the various types of players in the industry. We then discuss mHealth as a setting for digital entrepreneurship and draw on our empirical sample to describe new ventures in the industry. We conclude by outlining a research agenda focusing on entrepreneurship in emerging digital industries, structured around research themes of business model evolution, ecosystem and alliances, and innovation and data security.

2 The Emergence of the mHealth Industry

The emergence of mHealth was driven by two primary factors: (1) technological developments which enabled the introduction and increasing use of mobile Internet and the rise of smartphones and (2) the market need stemming from the increasing costs of healthcare.

2.1 Mobile Internet and Smartphones

Mobile Internet, or the use of the Internet via handheld devices such as mobile phones or personal digital assistants (PDAs), provides contextual freedom for the user, distinct from the stationary Internet confined in use to predetermined environments (Kim et al. 2002). Analog-based first-generation wireless technology was developed in 1979 and was gradually replaced in the early 1990s with second-generation (2G) digital radio technology which could accommodate text (Kim et al. 2007). Around 2001, third-generation (3G) technology began to take off, providing faster connection speed and bandwidth and also supported rich media such as video clips (Karjaluoto 2007). Fourth-generation services (4G) enable broadband wireless communication at home, at the office, and on the move and thus make the services provided by the Web and the Internet as well as a variety of other services such as multimedia and entertainment available to mobile users (Karjaluoto 2007). These leaps in technical capabilities drove increasing adoption rates of mobile Internet in the period 2005–2013, constituting a strong enabling technology base on which the mHealth industry could develop.

Further, mHealth was spurred by the growing use of smartphones. The concept of what exactly is a smartphone has evolved over time as technology has developed. According to one definition, smartphones are mobile devices with integrated wireless connectivity (Park and Chen 2007; Suarez et al. 2015) and thus differentiated from regular cellphones by having WiFi capabilities. Others have defined smartphones as phones that have an advanced operating system such as Android OS, Blackberry OS, Linux, Mac OS, or MS Windows Mobile (Giachetti and Dagnino 2014). Finally, Suarez et al. (2015) note that the definition of a smartphone evolved over time such that the requirements for smartphones in 2012 also included touch screens.

The adoption of smartphones grew 100-fold in the period from 2006 to 2014, establishing a large user base for emerging mHealth products and services. According to a report by Gartner (2006), the worldwide PDA and smartphone shipments totaled 3.65 million units in the first quarter of 2006, while pure PDA shipments were slipping. Shipments of smart mobile devices rose 55% year-on-year in the second quarter of 2006, signaling the beginning of the rapid growth phase of smartphones (Park and Chen 2007). In the third quarter of 2014, smartphone sales reached 301 million units, surpassing the sales of regular mobile phones. At that time (the end of our study period), smartphones accounted for 66% of the total mobile phone market (Gartner 2014).

2.2 Rising Healthcare Costs

Delivering affordable healthcare is one of the most pertinent challenges faced by any government, and rising healthcare costs were receiving increasing attention during the period of emergence for the mHealth industry. In 2010, worldwide total healthcare spending exceeded $4.2 trillion, equaling about 10% of GDP in OECD countries, increasing at an average of 5% every year (Anscombe 2011). The USA, for example, spends over 45% of the worldwide healthcare costs, while only having about 5% of the world population. Moreover, its population is aging, with an expected 20% of US population being over 65 by 2030, up 8% from 2009 (MobiHealthNews 2009). In addition to the aging population that creates a higher need for healthcare in the future, there is a trend toward a shortage of primary care physicians and nurses (MobiHealthNews 2009). While the US healthcare system may be facing more challenges than the healthcare systems in other countries, the trends mentioned above are not unique to the USA and are taking place around the world.

While the development and increasing use of mobile Internet and the rise of smartphone are enablers, i.e., factors that made mHealth possible from a technological point of view, the increasing costs of healthcare are the real drivers of this industry's emergence. Without the clear need to change healthcare systems around the world to alleviate some of the burdens they are facing, the mobile health industry would not have arisen. mHealth can bring more people, even those living in remote areas, in contact with physicians and healthcare providers, but can also be used to monitor individuals' behaviors and lifestyles, as up to 40% of all chronic conditions are attributable to people's own behavior (MobiHealthNews 2009). Wireless health solutions can monitor, analyze, encourage, and ultimately change behavior.

Ultimately, as for many digital industries, it was the combination of technological innovations and a compelling market need—the need for affordable healthcare—that gave rise to the mHealth industry. The combination of technological opportunity and market need created opportunities for not only mHealth firms but also for a vast ecosystem of existing players that surround these firms. We will elaborate on this ecosystem of other players in mHealth in the next section.

3 Overview of Players in the mHealth Industry

Although the most central players in the mHealth industry are those companies and organizations that create mHealth apps, products, and services, there are a whole range of other players active in the industry without which mHealth products or services could not exist. Figure 1 provides an overview of the different types of players. In the following, we will briefly discuss each category, providing examples and describing their roles in the mHealth industry. In so doing, we seek to create a comprehensive view of the multitude of stakeholders that came together in this new digital industry, highlighting the complex, interconnected ecosystem that entrepreneurs had to learn to navigate.

mHealth Firm The core players in the mHealth industry are those companies and organizations that create, develop, and market mHealth applications. These companies create applications such as remote monitoring tools for senior people (e.g., Halo Monitoring, Wireless Medcare), medication reminder tools (e.g., CareSpeak, MedMinder), monitoring apps for people with chronic diseases (e.g., Entra Health Systems, MedApps), weight loss and fitness tools (e.g., Fitocracy, WorkSmart

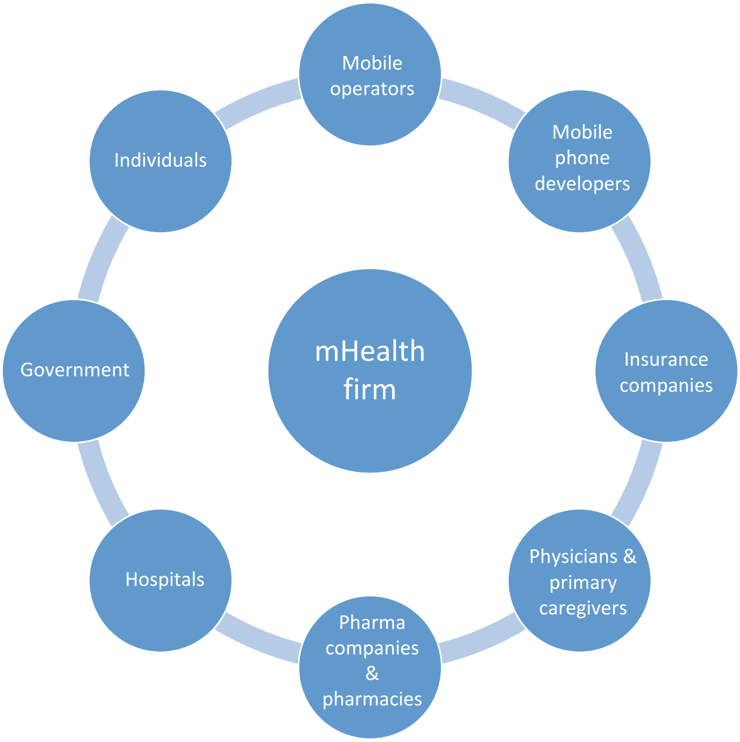

Fig. 1 Overview of players in the mHealth industry (authors' own figure)

Labs), and online appointment systems (e.g., ZocDoc). Within the category of mHealth firms, we distinguish between three types of companies depending on the products and/or services they develop. This categorization is based on an in-depth analysis of business models and ecosystem partners, utilizing our empirical dataset as well as expert interviews.

The first type of mHealth company focuses on improving the information transfer, administrative processes, and communication efficiency between patients, physicians, and hospitals—we label them *administrative* mHealth companies. An example of an administrative mHealth company is mVisum, which developed a mobile application that allows physicians to securely receive, view, and respond to patient data recorded at the point of care on their smartphones. mVisum also allows cardiologists to remotely diagnose heart attacks and allows them to communicate with people in the vicinity of the patient in order to better help him/her.

The second type of mHealth company, labeled *medical*, focuses on delivering medical care. An example is Vital Art and Science that developed a handheld application capable of diagnosing and monitoring age-related macular degeneration and diabetic retinopathy.

The third type of mHealth company generally falls into the non-regulated market category, creating wellness, fitness, and general health-related apps—we label them the *fitness and wellness* segment. An example of a company in this segment is GymPact, which is an app that encourages people to work out and go to the gym. Although FDA approval is not necessarily a requirement for companies in the administrative and medical segment, companies in the fitness and wellness segment will rarely apply for FDA approval and do not need it to be able to launch their products on the market.

Mobile Operators Mobile operators such as Verizon Wireless or Vodafone can be both passive and active players in the mHealth industry. As passive players, due to the increasing use of mHealth applications, operators can see increases in their customers' use of mobile data. But mobile operators can also take a more active role. US carriers such as Verizon Wireless, AT&T, and Sprint established partnerships or joint ventures with the aim of providing connectivity for, e.g., netbooks, eReaders, and portable navigation devices (MobiHealthNews 2009), thereby providing other devices with mobile Internet access using their network. Some mobile operators also invested in mHealth organizations. Verizon, for example, invested in NantHealth, a branch of NantWorks, in 2012. Other mHealth organizations established distribution partnerships with mobile operators, such as WellDoc with AT&T in 2010. Finally, signaling their dedication to the mHealth industry, some mobile operators such as Vodafone and Verizon even launched their own healthcare-focused business units (MobiHealthNews 2009).

Mobile Phone Developers Mobile phone developers, in addition to their basic phone manufacturing and technology-enabling role in the mHealth industry, also try to strengthen their positions in this industry by including their products in service offerings or by adding mHealth features to their phones. To this end, smartphone developers such as Apple and Nokia established alliances in the mHealth industry.

Apple partnered up with Epic Systems to include its iPhones in Epic System's Electronic Medical Record (EMR) service, and Nokia invested in the mHealth start-up Vision+Fund and collaborated in an SMS-based diabetes prevention program in India. Doro and Jitterbug, two companies developing phones for elderly people, established various mHealth alliances and thus went further than merely creating a phone that supports mHealth applications. Doro, for example, established alliances with Entra Health Systems and Medixine to include mobile diabetes management and a medication reminder service in its mobile phones. Jitterbug acquired a mobile personal emergency response service start-up called MobiWatch, conducted pilots with several wireless health vendors, and launched a Services Store with wireless health services (MobiHealthNews 2009).

Insurance Companies Insurance companies are important players in the mHealth industry for a number of reasons. First, while the advantages of mHealth are clear, one of the most important issues in the industry is the question: "Who will pay for it?" Convincing insurance companies to reimburse their customers for the use of mHealth apps was an important challenge, even reported by some as being more difficult than getting FDA approval (MobiHealthNews 2009). One of the first companies to succeed in getting reimbursement from insurance companies was CardioNet, whose Mobile Cardiovascular Telemetry Service qualified for Medicaid and Medicare reimbursement. After their initial qualification for reimbursement, however, some health insurance companies decided to cut the reimbursement rate for CardioNet's product, which led to the company's stock tumbling and forced it to cut costs (MobiHealthNews 2009). As a result of this struggle for getting and maintaining health insurance reimbursement, more mHealth start-ups tried pursuing a direct-to-consumer model or an indirect model in which employers would pay back the cost of the mHealth services of its employees to the mHealth start-ups (MobiHealthNews 2009).

In addition to serving as the payers, insurance companies are often influential in the mHealth industry as distribution partners for mHealth products and services. Hawaii Medical Services Association, for example, also known as the Blue Cross Blue Shield of Hawaii, was American Well's first distribution partner, thereby providing its insured members access to American Well's health marketplace service.

Finally, insurance companies can be the target customers of an mHealth organization. Truveris, for example, offers health insurers, among others, transparency into pharmaceutical benefit costs, design, and procurement, which should help them verify claim accuracy and manage pharmacy spend.

Physicians and Primary Caregivers Physicians and primary caregivers can take on a number of roles in the mHealth industry. First, physicians can be the target customers/users of the mHealth companies. Firms such as Modernizing Medicine and Phreesia focus on improving and alleviating some of the administrative burdens of physicians. Modernizing Medicine, for example, aims to help doctors save time by streamlining their handling of patient notes, bills, and prescriptions, and Phreesia digitizes the intake process of patients, by having patients fill out their medical histories on tablets. Moreover, physicians and primary caregivers can be parties involved in some mHealth applications, such as remote monitoring of patients and elderly people. MedApps, for example, creates a glucose monitoring tool that automatically sends the patient's data to his/her physician, who can keep track of the glucose levels. Halo Monitoring, on the other hand, is a fall detection system for elderly people that automatically notifies primary caregivers if a fall has been detected. Depending on the mHealth company's business model, physicians can be paying for the mHealth service (e.g., Modernizing Medicine) or can take on an active role without being the paying party (e.g., MedApps).

Pharmaceutical Companies and Pharmacies Both pharmaceutical companies and pharmacies also play a role in the mHealth industry. Pharmaceutical companies such as AstraZeneca and Janssen Healthcare Innovations (a Johnson and Johnson subsidiary) created their own mHealth apps, such as an educational app on epidermal growth factor receptor gene testing (AstraZeneca) and a medication adherence app (Janssen) (MobiHealthNews 2011, 2014). Moreover, some pharmaceutical companies have acquired mHealth firms, e.g., Merck's acquisition of Physicians Interactive (MobiHealthNews 2014).

Pharmacies, on the other hand, are frequently used as distribution channels for mHealth products, such as Adflow Health Networks, which placed blood pressure screening centers in various Rite Aid stores, and WellDoc, which also established an alliance with Rite Aid such that Rite Aid employees would get access to WellDoc's virtual diabetes management coach. Moreover, pharmacies can also be involved more actively in some mHealth apps, such as ZappRx' e-prescribing software, which alleviates the need for printed prescriptions.

Hospitals A large number of mHealth companies focus on products and services that are targeted at hospitals. Kit Check, for example, has created a product that simplifies the process of checking whether emergency kits and operating room equipment kits are fully equipped and whether the products in these kits are not outdated. Another company, Voalte, created a platform that allows nurses to communicate with each other more efficiently and allows them to respond to individualized messages. Healthagen's iTriage app provides patients with emergency room wait times and DocBookMD and TigerText facilitate secure messaging between hospital employees and physicians.

Government The government plays a largely indirect role in the mHealth industry, even though some governments or government departments have participated or even started mHealth programs. Regional governments in Egypt and Saudi Arabia, for example, have partnered with Qualcomm to set up country-wide mHealth systems. The US Department of Veteran Affairs started a pilot project with mVisum to get critical medical information to a physician while on their way to a patient's bedside. The White House worked with a number of industry partners to launch a free text messaging service for low-income expectant mothers, called Text4Baby.

The more prominent role of the government is ensuring that medical devices and applications meet regulations. mHealth organizations that want to market their products on the European market need to get a CE conformity mark before they can do so. mHealth organizations in the USA that work on data transfer between physicians need to make sure their products are FCC and HIPAA compliant, meaning that they must comply with the laws and requirements of the Federal Communications Commission and Health Insurance Portability and Accountability Act. Finally, the US Food and Drug Administration (FDA) can regulate any device that has a medical intended purpose (Thompson 2010). Before 2013, there only existed a set of FDA guidelines on which mHealth products needed FDA approval and on how to achieve this approval, but no fixed set of rules. The most frequently used approach of getting FDA approval consisted of showing that the products seeking FDA approval were "substantially equivalent" to other products already on the market (Thompson 2010). While the FDA rules issued in 2013 remained largely the same, they nevertheless provided mHealth organizations with more certainty and clarity regarding the FDA approval process (Thompson 2013).

Individuals Without individuals—patients and people aspiring to improve their health—there would of course be no mHealth industry. Individual users can be the ones paying for the mHealth products and services, as is virtually always the case in the non-regulated mHealth segment, but they can also be the end users without having to pay for the mHealth products and services, as when the health insurance companies cover the costs. Moreover, even in those mHealth applications targeted at physicians, hospitals, or pharmacies, improving the level of service provided to the individual patients is a key consideration.

To conclude, the mHealth industry encompasses a wide range of applications and a multitude of different types of players in a single industry, constituting a complex and dynamic environment for entrepreneurs to operate in. Table 1 summarizes the three main types of mHealth firms, i.e., administrative, medical, and fitness and wellness, as well as their primary customer segments, most relevant ecosystem partners, and example firms in each segment.

4 New Ventures in the mHealth Industry

We now turn to specifically examining the entrepreneurial ventures in the mHealth industry during its period of emergence. The descriptive analyses that follow will draw on a sample of young mHealth firms that was identified based on the annual MobiHealthNews reports from 2009 till 2013 and complemented with a list of mHealth companies receiving investments during that period, compiled by Rock Health. MobiHealthNews is an organization that focuses on providing news, research, and information on the global mHealth industry. Their annual reports contain information on all alliance deals in the mHealth industry and cover various types of organizations, such as start-up incumbents, hospitals, and industry organizations. Rock Health is a company that provides US-based mHealth start-ups with

Table 1 Overview of mHealth segments and key partners

Segment	Primary customers	Key ecosystem partners	Example firms and products
Administrative	– Hospitals – Physicians – Pharmacies and pharma companies	– Government – Individuals – Insurance companies	– mVisum: mobile application that allows physicians to securely receive, view, and respond to patient data – Phreesia: system that digitalizes the patient intake taking place in the physician's waiting room
Medical	– Individuals – Physicians	– Hospitals – Insurance companies – Pharmacies and pharmaceutical companies	– Vital Art and Science: handheld app to diagnose and monitor age-related macular degeneration and diabetic retinopathy – Neurovigil: product that measures brain waves and analyzes them; to be used for sleep and for degenerative illnesses
Fitness/ wellness	– Individuals	– Mobile phone manufacturers – Mobile operators – Insurance companies	– GymPact: app that encourages people to work out and go to the gym – MedMinder: medicine reminder product and app

Authors' own table

various forms of support, such as funding, access to potential partners, and office space.

The sampling criteria were the following:

- Firms had to be considered young ventures during the emergence of the industry. To this end, the sample included firms that were founded between 2005 and 2013.
- Firms had to be primarily active in the mHealth industry. They could be active in the administrative, fitness and wellness, or medical segment, as long as this was their primary set of activities. In other words, only firms that were labeled as an "mHealth firm" in Fig. 1 were included in the sample. Hospitals, physicians, insurance companies, and pharmaceutical companies involved in but whose primary activity was not mHealth were not included in the sample.
- Firms also had to be independent ventures, meaning that they were not the subsidiary of another firm. By only including independent firms in the sample, the sample is more homogeneous in terms of its ownership structure and better reflects entrepreneurial ventures active in a digital industry.

A total of 214 firms were identified meeting these criteria. For 21 of them, not enough information was available, so our final sample has 193 ventures, founded between 2005 and 2013, with their primary activities in the mHealth industry. Over half (52%) of firms in our sample were between 3 and 5 years old, 9% of firms being younger than 3 years, and the remaining firms being older than 5 years at the time of the data collection in 2014. About 52% of our sample was active in the fitness and

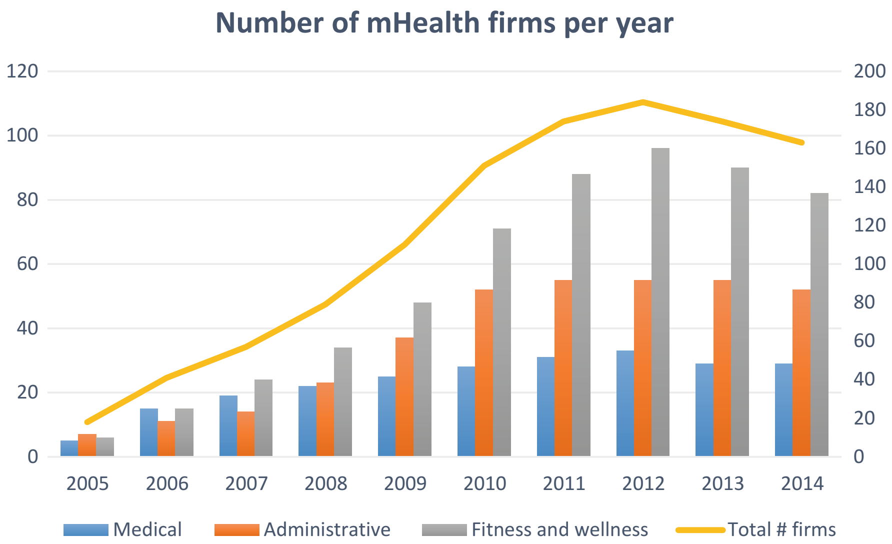

Fig. 2 Overview of number of mHealth firms per year (authors' own figure)

wellness industry segment, with 30% firms in the administrative segment and the remaining 18% in the medical segment.

Figure 2 provides an overview of the number of mHealth firms per industry segment per year. As can be expected, new ventures in an emerging industry will initially be most prevalent in the least regulated segments (i.e., fitness and wellness and administrative). Toward the end of the study period, the industry is showing some early signs of maturing, as illustrated by the decline in the total number of new firms. This may suggest that digital industries transition faster through the industry emergence–growth–maturity–decline cycle than non-digital industries. Important to point out though is that while mHealth had grown and matured, it could still not be considered a mature industry at the end of the study period—norms and institutional structures were still being formed and a dominant design had not emerged (Agarwal et al. 2002).

While MobiHealthNews and Rock Health do not uniquely cover the US mobile health industry, most of the firms covered in their reports—and consequently most of our sample firms—were active in the USA, with only 4.3% of firms being founded outside of the USA. We used Wasserman (2017)'s categorization of US states as primary, secondary, or tertiary start-up hubs to get further insights into the location of mHealth start-ups throughout the USA. As can be expected, nearly half (46.8%) of start-ups are active in primary states California and Massachusetts. Secondary markets Illinois, New Jersey, New York, and Texas represent 16.5% of the mHealth firms with the other 32.4% spread throughout the other 44 states (see Fig. 3).

The average number of interorganizational relationships (IOR) per firm is 10.78, with a median value of 7. Each firm had at least one IOR, with the maximum number of IORs being 86. Figure 4 provides an overview of the distribution of the types of

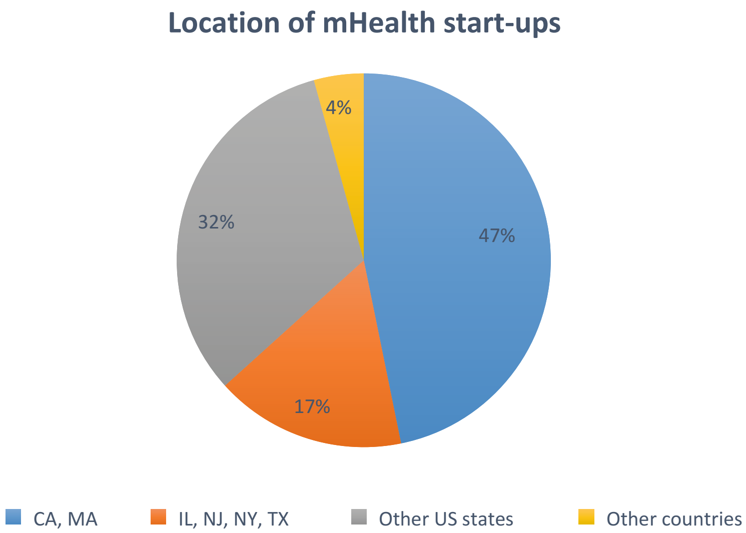

Fig. 3 Geographic location of mHealth start-ups (authors' own figure)

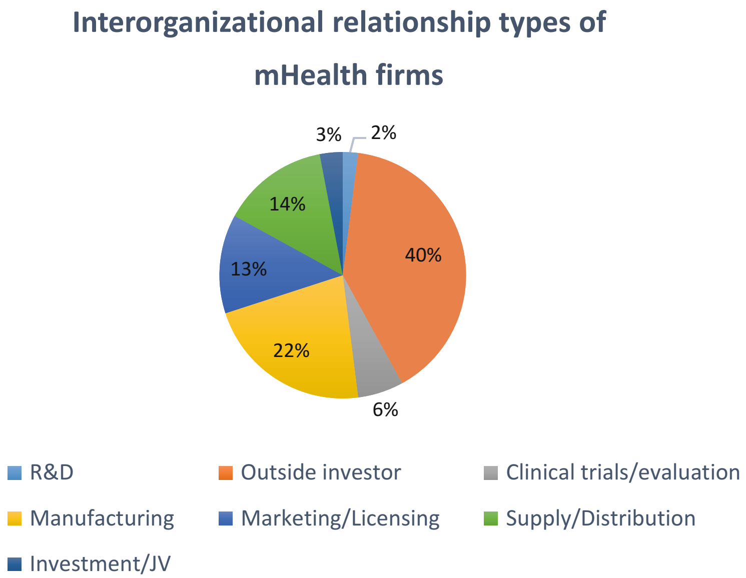

Fig. 4 Percentage breakdown of interorganizational relationship type (authors' own figure)

IORs held by the firms. Taking together all firms and observation years, the majority of IORs were outside investor ties, meaning that the sample firms received investments from a third party. About a decade after the industry emerged, 62% of mHealth firms were VC-backed. The second most frequent type of ties were manufacturing ties, followed by supply/distribution, marketing/licensing, clinical trials/evaluation, joint ventures, and R&D ties. The interconnectedness between mHealth organizations and other players makes business models complex and also underlines the importance of taking an ecosystem perspective when studying novel, digital industries.

5 A Research Agenda: Digital Entrepreneurship in Emerging Industries

The preceding sections of this chapter have highlighted several features of the mHealth industry as a case of a new digital industry. In this section, we build on those features to suggest interesting avenues for future research. A first such avenue is the business model. Due to the novelty of the industry, the lack of regulation, and the interdependency between a variety of different players, business models in the mHealth industry are likely to be complex and subject to change. We will discuss specific challenges that mHealth firms face and how future research can address this. The second research avenue that we propose is the ecosystem. Our descriptive analysis identified that young mHealth firms have a high number of interorganizational relationships and that there is quite a diversity in the type of partners they have. Getting products or services to market typically requires collaboration with various partners, such as physicians, pharmacies, hospitals, and insurance companies. We will highlight some of the challenges that the three types of mHealth firms face regarding their ecosystem development.

As a third future research avenue, we will elaborate on innovation and the role of digital technology in the mHealth industry, as well as some challenges related to that in terms of data security and privacy. This is a timely topic (e.g., Facebook and its 2018 data privacy scandal) that can also have a significant impact on customer adoption (Fodor and Brem 2015) and consequently on the success of mHealth firms and the industry itself. Figure 5 summarizes these three future research avenues. Before delving into further detail on each of these three avenues, we will first discuss the research context of new ventures in an emerging industry.

Emerging Industries and New Ventures An emerging industry is an industry in which there is no dominant design, where the customers are unclear, the product attributes undefined, and the industry value chain poorly established (Santos and Eisenhardt 2009). Because of this high uncertainty, firms will more likely have to experiment with different strategies and business models before they find a business model that adequately tackles the uncertainty of emerging markets (Teece 2010). This is especially the case for new ventures which, as young organizations, do not have a proven track record or reputation that they can rely on. Andries et al. (2013) have shown that the new ventures in their study changed their business models anywhere from once every 2 years to multiple times a year, until the dominant industry business model became clear.

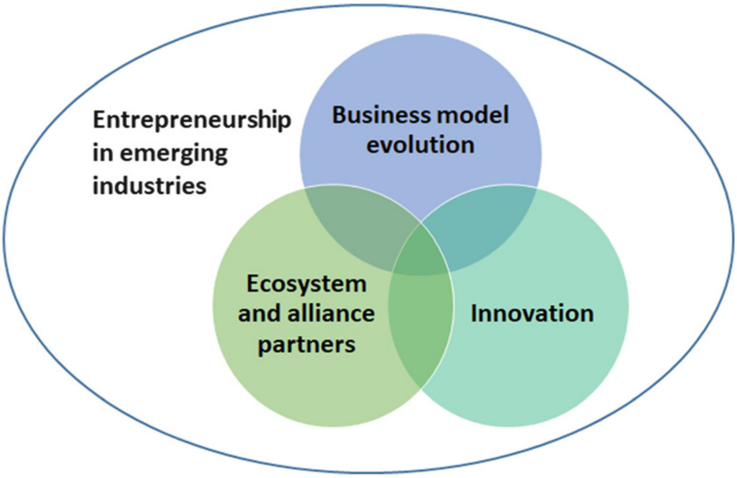

Fig. 5 Future research avenues for mHealth and digital entrepreneurship research (authors' own figure)

New ventures also typically have limited financial, technological, and human resources and little power over other actors (Ambos and Birkinshaw 2010). Their actions will therefore primarily be driven by short-term goals and performance, such as new product introductions and survival, rather than profitability (Ambos and Birkinshaw 2010; Graebner 2004). Nonetheless, because the industry itself is not yet established, firms in emerging industries will not only need to legitimate their own actions, but will also need to overcome the newness of the industry, which they can do by acting as institutional entrepreneurs that legitimate their ideas, business operations, and ultimately the emerging industry (DiMaggio 1991; Maguire et al. 2004; Rao et al. 2000). Entrepreneurs can do this by changing customer perceptions, modifying competitive conditions, restructuring value chains, and instilling societal change (Agarwal et al. 2017). Entrepreneurs in emerging industries also typically need to build an ecosystem by establishing relationships with a different number of players, thereby creating a highly interrelated setting in which players with different goals need to work together to be able to achieve their goals. When both the technology and the market are new, as is the case in mobile health, gaining legitimacy within an ecosystem is more challenging than when either the technology or market is already well established (Fisher et al. 2016; Kuratko et al. 2017).

Finally, in emerging industries, norms are typically not crystallized (Agarwal et al. 2002) and legislation may be lagging. In the mobile health industry, the FDA only published its first report on guidelines and regulations for mHealth apps and devices in 2013 (MobiHealthNews 2014), some 10 years after the first mHealth firms were started. Similarly, HIPAA was expanded to better protect individuals and their electronic health records in 2013 (Elliott 2013). Given that many digital firms' business models are based on big data, legislation on how these data can be used and stored is important, especially when data is sensitive, as is the case in a health context. Innovation and data security are thus important aspects that arise in new digital industries that governments should create regulating frameworks for and firms must take into account when building a business model.

Business Model Evolution and Challenges Digital industries are characterized by rapid changes. As such, business model changes are not only likely, but possibly also necessary. It is therefore important that future research focuses on not only understanding why some firms engage in business model changes and others do not, but also what the performance implications are for new ventures in an emerging digital industry. Nonetheless, only a few papers (e.g., Andries et al. 2013; Saebi et al. 2017) have focused on business model change in entrepreneurial ventures and these studies did not explicitly focus on digital entrepreneurship, a setting where business model changes are likely even more important than in more traditional contexts. Future research could therefore benefit from comparing business model changes in "traditional" entrepreneurial ventures and in digital entrepreneurial ventures.

In addition, the three different mHealth segments offer a comparative context to study some unique business model challenges related to revenue generation. For firms in the administrative segment, for example, where the target customers are typically doctors, hospitals, or pharmacies, the challenge is to figure out who will pay for the service. Electronic health records (EHRs), for example, safely store patient information and make it accessible to doctors, hospitals, pharmacies, and patients themselves. While all of these parties clearly benefit from the use of EHRs, it is less clear which party should pay for the cost of the EHR. In the medical segment, the main challenge is to convince insurance companies to reimburse mHealth products and services. Patients will not want to use mHealth devices for their health if these are not reimbursed by insurance companies while traditional devices are. Finally, in the fitness/wellness segment, the challenge is usually not to find adopters, but the challenge is to find enough paying customers. In response to this, firms in this segment have increasingly changed their business models to B2B models. It is thus clear that especially the value capture component of the business model is troublesome. Future research should investigate how entrepreneurs in new digital industries can design and implement business models that allow effective value capture.

Role of the Ecosystem and Alliance Partners A further topic on which few studies have focused is the role that firms' alliance partners and the business ecosystem have in an emerging digital industry. Alliances refer to "voluntary cooperative inter-firm agreements aimed at achieving competitive advantage for the partners" (Das and Teng 2000, p. 33), while a business ecosystem can be seen as a group of companies that simultaneously create value by combining their skills and assets when individual companies are not capable of commercializing a product or service by relying on their own competences (Clarysse et al. 2014). A firm's set of alliance partners can provide the firm with resources that are necessary for the firm to carry out its business model. Moreover, firms are increasingly part of ecosystems and their ability to create value depends on their complementors in the ecosystem (Kapoor and Lee 2013). Effective strategies will thus depend on firms' abilities to accurately evaluate the risk for all parties involved in the ecosystem, ensuring opportunities for key complementors and deciding whether to be a leader or follower in the ecosystem (Adner 2012; Adner and Kapoor 2010; Priem et al. 2013).

The success of legitimation within an ecosystem also depends on the novelty of the technology and the market. If both are novel, the challenge for new enterprises will be greater (Kuratko et al. 2017). This is the case in the mHealth industry, where firms in each segment face different ecosystem challenges. In the administrative segment, the main challenge for firms is to implement the products and services across the value chain. Solutions that simplify administration in mHealth are only effective when they are implemented across multiple actors in the value chain. Taking the EHR as an example again, the value will be the greatest if all doctors, regardless of network or hospital affiliation, will use the same EHR, such that all patient information is centralized. As such, a challenge for firms in this segment is to get sufficient scale in adoption for their products and services by various value chain actors, such as physicians, hospitals, pharmacies, and other medical providers. In the medical segment, the role of ecosystem players is mostly to get the products to the customers. Most products in this segment are prescription-only, and patient adoption and payment will to a large extent depend on doctors' willingness to prescribe these products. Finally, in the fitness and wellness segment, distribution takes place through app stores, insurance companies, and pharmacies. Getting these actors on board is thus an important step for mHealth firms. Overall, while the importance of ecosystems and alliance partners in emerging industries is clear, future research could investigate how the entrepreneurial firms in emerging industries can shape their ecosystems, as well as how the ecosystems in turn influence the development, growth, and success of the firms.

Innovation and Data Security Emerging digital industries, such as mHealth, are typically based on technological innovations that make the novel industry possible. That is, technological innovation can be seen as the antecedent of industry formation. On the other hand, emerging industries and markets can also lead to new innovations, such as frugal innovations, which are solutions designed specifically for low-income market segments (Agarwal and Brem 2012). mHealth products and services have been able to improve the lives of many people living in low-income homes, for example by making remote monitoring and video doctor consultations possible. Future research could further investigate the link between industry emergence and such frugal innovation.

A second stream of future research could focus on the boundaries of innovation and the choices that firms in digital industries make regarding privacy concerns. While mHealth is a more regulated digital industry than others, because of worldwide legislation that protects individuals' health records (e.g., HIPAA in the USA), firms in the mHealth industry still need to make choices regarding how they will treat the information from their user bases and to what extent this will be kept private. This is not only important from a legislative point of view but also because the choices that firms make regarding the privacy of their users' information will impact the adoption of their product/service which in turn can influence the firm's success (Fodor and Brem 2015). When looking at the three segments in mHealth, this choice

Table 2 Role of technology and key challenges per mHealth industry segment

Segment	Role of technology	Challenges
Administrative	Technology = enabler; digital entrepreneurs	– Business model: Who will pay? – Ecosystem: Implementation across value chain – Data security: Regulated by government
Medical	Technology = product; digital technology entrepreneurs	– Business model: Reimbursement – Ecosystem: Offer apps via indirect channels (e.g., physicians, hospitals) – Data security: Data is essential part of product
Fitness/ wellness	Technology = platform; digital entrepreneurs	– Business model: Adoption; getting paying customers – Ecosystem: Offer apps via indirect channels (e.g., app store, pharmacies) – Data security: Who can use data? Are there restrictions?

Authors' own table

seems to be particularly salient in the fitness and wellness segment, because it is the least regulated. In the administrative segment, data is protected by government regulation, while in the medical segment, data is an essential part of the medical device that often measures and transmits data to medical professionals. As such, data is also protected. Products and services in the administrative and medical segment are also more often paid for directly by the user or by a third-party payee, which makes it less necessary for firms to use user data to generate revenues. This is in contrast with free apps or platforms, which is often the case in the fitness and wellness segment. While innovation thus can bring important advantages to society, especially in lesser-regulated segments and industries, users should be cautious about sharing their data with firms and/or using free apps and services. Future research can look further into business models that allow users to better protect their data while still generating revenues for the focal firm. Table 2 summarizes the key challenges per industry segment.

6 Conclusion

This chapter took an industry perspective to digital entrepreneurship, exploring the emergence and growth of a novel digital industry, mHealth, with focus on the new ventures within the industry. Our findings suggest that ventures in new digital industries may face environmental conditions and challenges that are distinct from both traditional, non-digital ventures and from digital ventures that are transforming more mature industries. It is therefore important that researchers do not only focus on traditional ventures that transition toward digital industries or add digital components to their business models but also on the "born digital" ventures founded in a novel, emerging, digital industry. Our data showed that mHealth ventures are characterized by their interdependencies with many types of industry players, reflected in a high number of interorganizational ties and geographic concentration. Taking an ecosystem perspective while studying digital entrepreneurship is therefore important. Further, given the fast pace that characterizes digital industries, future research could examine business model evolution of digital ventures and the implications for both venture- and industry-level outcomes. Finally, because these industries are at the forefront of technological innovations, future research could further investigate the reciprocal link between innovation and digital entrepreneurship. Frugal innovation, for example, seems a promising topic for future research as digital technologies can play a key role in enabling firms and society to produce more efficiently.

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Entrepreneurship as an Innovation Driver in an Industrial Ecosystem

Markus Hofmann and Ferran Giones

Abstract Understanding how a new digital technology can translate into a valuable innovation is a challenge for established players and new entrants. For industrial players in an ecosystem, it can be both a threat and an opportunity. Furthermore, the new technologies open collaboration opportunities between corporates and start-ups. But it remains unclear what are the consequences of opening up and whether it has an impact on the innovation dynamics in the industrial ecosystem.

We use the case of the wind industry in Denmark, as a maturing industrial ecosystem, to study when and how the new entrants (technology entrepreneurs) have had an impact on the innovation dynamics. We first combine archival data with interviews to build a historical account of the evolution of the industrial ecosystem; then we incorporate data from the new entrants in the industry to specify the types of innovations that the most recent digital technology entrepreneurs have triggered.

The results suggest differences in the innovation dynamics depending on the value chain position. While some activities have remained rather closed (for instance, the technological development of the core elements in the wind turbines), the operations and maintenance activities have profited from digital technologies introduced by new entrants. Using these insights, we present and discuss suggestions to institutional actors interested in protecting the innovation leadership of their regional industrial ecosystems.

Keywords Innovation ecosystem · Digital entrepreneurship · Wind industry · Digital innovation

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1 Introduction

New technologies have set a whole new standard of innovation with constant groundbreaking innovation. Recent examples are the development of digital technologies such as drones, AI, IoT, VR, or Blockchain (Cohen et al. 2017). Established industrial ecosystems often observe these emerging digital technologies as a threat but also as an opportunity. Examples of the use of drones to support maintenance operations (PwC 2016) or IoT sensors data to improve supply chain operations (Li 2013) provide support for the latter.

The non-digital industrial players often struggle to keep up with the digital innovation pace; see for example the case of Kodak (Lucas and Goh 2009), even losing the attention of institutional actors and investors. This phenomenon can not only occur in traditional industries such as automotive or general manufacturing, but also in recently emerged industrial ecosystems such as the renewable energy industry. Against this backdrop, we would expect that the interaction between new technology entrepreneurs (i.e., digital start-ups) and industrial ecosystems could have a positive effect on the innovation pace of the established ecosystems and in their overall competitiveness (Nambisan and Baron 2013). Still, we know little on whether and how this process of interaction and co-evolution unfolds, leaving open the intriguing question of to what extent do entrepreneurs contribute to the introduction of new technology innovations in industrial ecosystems? We examined this question focusing on digital innovation to see if the characteristics of digital technologies facilitate the participation of new entrants.

In order to describe how this process occurs, we engage in the study of an industrial ecosystem under competitive pressure. We selected the case of the leading players in the wind industry (Vestas and Siemens) as it is an industrial ecosystem (mostly located in Denmark) that is under intense pressure to increase its innovation pace. The recent reference on how the solar energy industry pioneers lost its leading manufacturing position to cost-oriented producers (Zhang and White 2016) has triggered an urgent search for innovation opportunities to fend off new competitors.

We combine archival data and interviews with experts and actors in the industrial ecosystem to find answers to our research question. We first present a historical account of the innovation dynamics and the evolution of the wind energy innovation ecosystem. Building upon the interviewees' insights, we detail the new entrants' interactions and contributions to the challenges and opportunities in the industry.

Our data suggests that the entrepreneurs' contribution is strongly influenced by the different dynamics in the value chain activities. While the core wind energy technology development has become a rather closed process, the operations and maintenance activities have opened opportunities for new entrants introducing digital technologies.

The findings from this study contribute to the emergent literature on the interaction between innovation ecosystems and technology-driven entrepreneurial ecosystems (Thomas et al. 2017). We also generate valuable practical insights to institutional actors interested in protecting the innovation leadership of their regional industrial ecosystems, suggesting the need for a more active role in order to keep the value-added activities in the region.

We start with a review of the recent discussion on innovation and entrepreneurial ecosystems. We continue with a presentation of our research design and data sources. Then, we present a historical account of the wind industry ecosystem evolution and our findings from the fieldwork interviews. Finally, we outline the implications and takeaways for researchers and industry participants.

2 Innovation and Entrepreneurial Ecosystems

It is difficult to find a more popular word in business and management discussions than ecosystems. The concepts of innovation ecosystems and entrepreneurial ecosystems are often used in business and policy discussions. It appeared as a new term to discuss about the necessary actors and relationships in order to have innovation and/or entrepreneurship in a region (Ritala and Almpanopoulou 2017).

From a research perspective, the increasing popularity of the term raised some questions from scholars. One of the strongest critiques is the recent piece by Oh et al. (2016) that questions why the prefix eco- is used; the authors argue that most innovation ecosystems are not natural emerging systems but instead driven by key actors that push forward the innovation. The basic definition of an innovation ecosystem as a diverse group of organizations that co-evolve and co-create value (Adner and Kapoor 2010) can be ambiguous, in particular if we compare it with other existing concepts such as clusters or regional innovation systems (RIS).

2.1 Ecosystems, RIS, and Clusters

What makes an innovation ecosystem different from a cluster or a RIS? Clusters have a strong regional focus; they are agglomerations of organizations that reinforce the productivity of each other and strongly benefit from their geographic proximity. Plus, there is the idea that regional clusters compete against other clusters in the same industry across the globe; this explains the interest of policy makers to promote and support them to keep their international competitiveness (Scaringella and Radziwon 2017). The regional innovation systems (RIS) are broad public initiatives to facilitate innovation activities in a region; a common example are triple-helix initiatives that aim to increase the collaboration between university and industry in a region (Ritala and Almpanopoulou 2017). The differential aspect of innovation ecosystems is that they are market driven, meaning that even if the government or public institutions play a role in it, it is mostly the private actors that drive the co-evolution of the value creation and capture activities.

This implies that innovation ecosystems are not limited to a region, having global connections and actors, and that the market demand is likely to be the driver of technological evolution and structure changes. These aspects are the differential elements that justify the use of the prefix eco- to differentiate them from clusters or regional innovation systems (Ritala and Almpanopoulou 2017).

2.2 Entrepreneurial Ecosystems

From a policy maker's perspective, global innovation ecosystems are market driven and led by large firms that influence on the pace and technological evolution, so there are limited options to influence on their growth and evolution. As a result, the discussion has moved toward the early stages of ecosystem formation, introducing yet another new type of ecosystem: entrepreneurial ecosystems. These share many similarities with the abovementioned innovation ecosystems, but also some differences that deserve specific attention.

Entrepreneurs are the key actors in this type of ecosystem, but instead of being industry specific, they grow around a specific underlying technology [e.g., nanotechnology (Colombelli et al. 2014)]. They are globally connected with other new entrants aiming to explore the potential applications of a still underdeveloped technology (Autio et al. 2018). In this context, the role of the government is to support networking activities or complementary resources (Spigel 2017), but the dynamism of the entrepreneurial ecosystem largely depends on the existence of specific technical knowledge actors coming from either the industry or universities (Stam 2015).

2.3 Interaction Between Entrepreneurial and Innovation Ecosystems

In their description of the different stages of an innovation ecosystem, Dedehayir et al. (2016) mention that in the later stages, as the ecosystem matures, it reaches a point where there is either self-renewal or death. In this stage, the leaders of the ecosystem play a vital role in the generation of new innovations and in the restructuration of the dependencies and roles in the ecosystem.

It is at this point where new entrants in the innovation ecosystem contribute to the exploration of new opportunities, introducing new technologies or new business models that could contribute to the overall development (Nambisan and Baron 2013). As entrepreneurs in technology-driven entrepreneurial ecosystems have to make a choice on application and location, they start interacting with existent innovation ecosystems. This generates arguably a tension between technology-driven entrepreneurs and market-driven firms, both competing at a global scale to attract resources and growth. Considering their different logics, our research question is to explore when and how do these new entrants contribute to the innovation ecosystem? This is a puzzling question as regional policy makers support nascent entrepreneurial ecosystems with the ambition to have a next generation of large firms that support the region' growth, but this might not always be the final outcome (Brown and Mason 2014; Spigel 2017).

3 Research Design

The wind industry has not yet reached full maturity, but it has become a global innovation ecosystem. It has been in constant transformation due to new technical and environmental conditions and boasts high innovation dynamics (Simmie 2012). It is a global innovation ecosystem that includes manufacturers, suppliers, research institutes, universities, utility companies, service providers, consumers, etc. The Danish wind energy industry is an interesting case to explore as it has been in the epicenter of the emergence and development of the ecosystem (Flyvbjerg 2004). Given the explorative nature of this research, we chose a case study research to study the contribution of digital technologies entrepreneurs as an innovation driver in an industrial innovation ecosystem (Eisenhardt 1989; Ravenswood 2011).

The data sources consist of archival documents and interviews. The case study is built with various data sources to represent the phenomenon coherently (Eisenhardt and Graebner 2007). The archival data consist of prior reports, news articles, and research on the innovation ecosystem of the Danish wind industry, reports from the Danish wind industry (including onshore and offshore actors and activities), newspaper articles, and articles about the historical development of the wind industry. In addition to the archival documents, interviews with actors in the ecosystem provided rich insights on the innovation dynamics and the contribution of new entrants. Interviews with experts, managers, and researchers in the ecosystem were carried out for a holistic dataset (Robinson 2014).

The interviews (semi-structured) were conducted between December 2017 and April 2018. Given our explorative approach for this research, we selected the first interview partners from our network, based on their active involvement in the ecosystem. Following the interviewee's recommendation and network, we selected further interviewees (snowballing approach).

We were careful in our sampling strategy to choose an equal number of observers (such as academic researchers) and active actors in the ecosystem. An overview of the interviewees and their background can be seen in Table 1. Finally, we used data from companies listed in Crunchbase (start-up funding database managed by Tech Crunch) to get an overview of start-ups in the ecosystem. Thereby we selected all start-ups which stated that they are corresponding to the wind energy industry, located in Denmark and which are founded after before 2006. We added some further start-ups to the list that we discovered during our research and which fit to the criteria.

Table 1 Interviews with wind energy industry ecosystem actors (December 2017–March 2018)

Role	Position	Background	Duration (min)
Engineer 1	Junior engineer at Siemens Gamesa	Master Student working at Siemens Gamesa	35
Engineer 2	Program manager at Danish Wind Industry Association	Leading Sub-supplier Development Program	240
Director 1	CEO and Cofounder	Founder and CEO of one of the main lifting and transportation providers in the wind industry	15
Director 2	CCO	CCO at an international turbine service provider and former Head of Product marketing at Vestas	25
Director 3	CEO and Cofounder	Service and repair start-up, which uses new digital technologies	35
Researcher 1	Professor for Wind Energy	Professor at SDU and former DTU professor	60
Researcher 2	Professor in Sociology, Environmental and Business Economics	Professor at SDU and consultant for Innovation and Business development	30
Researcher 3	Professor in Supply Chain Management	Professor at SDU	27

Source: authors' own table

For the data analysis, a triangulation approach was chosen by combining archival data, interviews, and desk research (Leech and Onwuegbuzie 2007). First, we built a historical account of the industrial innovation ecosystem after compiling facts and perspectives from our data sources. This historical account helped to identify key stakeholders and to assemble a value chain. During this process, we marked two processes, turbine development and park development, which split the innovation ecosystem. Prior research in the Danish wind innovation ecosystem, for instance, triple-helix taxonomy, provides an introduction into the innovation dynamics (Brink and Madsen 2016; Andersen and Drejer 2009). Next, we supplemented unacknowledged areas in both processes with interviews. Thereby, interview transcripts are integrated to enrich data with personal narratives and quotes.

To understand the phenomenon, we applied an iterative process of switching between data and theory. To provide further evidence of the entrepreneurial dynamics, we analyzed the list of start-ups in the Danish wind industry from Crunchbase. Using as search criteria their location in Denmark and that their description contains a connection to the wind energy. The total number of companies meeting these criteria was 21. Some of the listed companies, like Vestas, are, however, not part of the research object. For this reason, we exclude all companies which were founded before 2007. All companies which meet these for criteria are listed in Table 2 (in the results section).

Table 2 List of recent start-ups within the Danish wind energy ecosystem

Entry year	Start-up name	Product/service	Area in the value chain	Digital innovation
2009	Forida	Ultra-high-performance concrete	Turbine development	No
2007	Global Lightning Protection Service	Hardware lightning protection and digital lightning system that inspect turbine	Operation and maintenance	Yes
2008	Global Wind Service	Global technicians' supplier	Operation and maintenance	No
2016	KiteX	Drone wind energy	Turbine development	Yes
2014	Klenergy Tech	Store electric power with hardware solutions and blockchain technology	Operation and maintenance	Yes
2013	Power curves	Upgrading turbine blades panels	Operation and maintenance	No
2016	RopeRobotics	Unique blade repair by using robotics and additive manufacturing	Operation and maintenance	Yes
2013	Vaavud	Crowdsourced weather service	Operation and maintenance	Yes
2016	Wind Power LAB	Automated wind turbine blade defect detection and assessment through AI	Operation and maintenance	Yes
2008	Windar Photonics	Laser-based anemometer	Operation and maintenance	Yes

Source: authors' own table

4 Historical View on the Development of Denmark's Wind Energy Ecosystem

The development of wind turbines as new renewable energy source in the last 40 years is astonishing, from starting out in the 1970s with 10–30 kW turbines to, nowadays, giant turbines in our seas with rotor diameters of 160 m and capacities around 9.5 MW (Renewable Energy Agency 2018). However, the sticking point behind the development of the wind power energy is the levelized cost of electricity (LOCE), meaning the produced energy compared to the construction, production, installation, and O&M costs.

The technological evolution was hugely driven by the Danish wind power ecosystem. The relatively young industry has long benefited from the Danish hands-on R&D policy and the technical "smaller but safer" approach (Klaassen et al. 2005). A combination of elements made this possible: the public interest in energy source alternatives, investment subsidies, balanced and well-timed R&D, public procurement support, and last but not least, a focus on small reliable wind turbines lead to the strong innovation and diffusion of wind energy in Denmark. This approach generated better results than the ones of nearby big nations like Germany or the UK (Klaassen et al. 2005).

Drejer and Andersen divide the development of the Danish wind industry into a formative stage, a growth stage, and a globalization stage (Andersen and Drejer 2008). We use this classification to explain the chronological evolution of the Danish wind turbine ecosystem. However, we add a restructuration phase to the globalization stage to depict recent changes in light of new challenges and emerging technologies.

4.1 First Phase: Formative Stage: 1972–1980

The emergence of the modern Danish wind industry was triggered by the energy crisis and economic recession in the 1970s. Back then, a handful of wind energy idealists, enthusiastic amateurs, and entrepreneurs sparked interest in wind turbines as an alternative and freely available energy source. This small group of people collaborated closely to collectively achieving their goal of simply creating energy from the wind. Thereby, they took advantage of all the practical knowledge and experience they could gather. Their theoretical knowledge about wind turbines was still limited, yet they enjoyed success by practically testing new ideas and concepts. This is similar to what nowadays is described as a Fablab space with "makers" running experiments to develop new products (Mortara and Parisot 2017).

The early success attracted more and more players from the agriculture, machine, and boat industry (Andersen and Drejer 2008; Jensen 2003). This was different to most other countries which let large high-tech companies develop their big wind turbines completely, suggesting an entrepreneurial driven co-evolution dynamics between the promising technology and new applications (Giones and Brem 2017). The Danish approach proved to be more reliable and thus successful. Along the supply chain, small companies and entrepreneurs collaborated to jointly develop and build small wind turbines (Meyer 1995).

4.2 Second Phase: Growth Stage: 1980–2000

The second phase of the development of the Danish wind industry was initiated by the introduction of the Energy Plan, a subsidy-based program started in 1981. The reason was to reduce the dependency on energy imports. The plan supported wind energy producers by allowing them to feed energy into the power grid and to receive minimum (subsidized) prices for their production (Andersen and Drejer 2008). Shortly after, the main governmental support started shifting from manufacturers toward operators, in order to stimulate further market adoption of the new technology (Klaassen et al. 2005). This well-thought-out support program by the government, paired with the experience from a large number of installations, equipped the Danish manufactures with the first-mover advantage and gave them significant benefit over other companies (Smith 2011).

4.2.1 Building Trust and Legitimacy in an Emerging Industry

A key event in this private and public joint effort is the foundation of the Risø test station for wind energy research. The center, still now, connects scientific researchers with wind turbine manufacturers in Denmark. The Risø test center was known at that time for testing new designs and principles applying aerodynamic theory and putting them into practice (Andersen and Drejer 2008). With these steps, the development of wind turbines advanced from trial and error to a scientific and professional approach. With the majority of actors from the formation phase still involved, most of the learning took place through experimentation (Karnøe 1999).

The large demand for turbines in Denmark reflects the success of the Danish government incentive system. Besides the growing Danish market, an international market emerged for wind turbines which attracted new suppliers and manufactures. In addition to the increased demand, the request for bigger and more reliable turbines came up. These requests turned the wind turbine industry into a more complex and elaborated ecosystem. Danish actors tackled this problem by strengthening the collaboration among the main actors' supportive institutions, manufacturers, and suppliers.

The promising future of the wind industry attracted further suppliers from other industries and led to existing suppliers specializing solely in wind turbines. This additional knowledge from the supplier side boosted the development and amplified the supplier importance. In doing so, it highly increased the collaboration between manufacturers and suppliers.

4.2.2 Unusual Collaboration Arrangements with Suppliers and Competitors

Situations occurred where engineers from the supplier became temporary employees in the manufacturer's firm. Furthermore, cross-firm meetings and seminars with suppliers were hosted by supportive institutions. Even competitor collaboration could be seen if major breakdowns or problems occurred in the ecosystem. The tight collaboration was facilitated by the common goal of the main actors: boosting wind energy and showing its full potential (Andersen and Drejer 2008). Despite the high level of collaboration and co-creation, the manufacturers' supplier structure was almost flat; this had advantages but also caused two new problems in the industry: manufacturers received only parts without any system integration and suppliers were only allowed (through exclusivity agreements) to work with one of the main manufacturers (Megavind 2013).

4.3 *Third Phase: Globalization Stage 2000–2006*

The profound collaboration and collective technology development in the growth phase was strongly affected by new international directives and the new technical level wind energy had reached. The directive for liberalization of the European energy market, enacted 2001, allowed to trade electricity on the European energy market (Meyer and Koefoed 2003). Wind energy benefited from the directive; locally available wind electricity could be traded where it was in demand.

4.3.1 Park Developers as Innovation Intermediaries

Besides the reform, wind turbine technology reached the level at which energy generation became attractive for investors. At this point, investors started to promote large wind power parks, placing several wind turbines in a limited space. This new high-volume implementation could not be completely handled by turbine manufacturers and thus opened options for intermediaries. These were quickly taken up by park developers, which had tremendous consequences for the whole industry. Park developers quickly started to compete with manufacturers in park tenders, whereby developers came up with new competitive parameters and more successful business models with lower operation costs. This situation rearranged the supply system, in which wind turbine manufacturers now act as suppliers for wind park developers (Andersen and Drejer 2008).

This new structure also entailed a new business rivalry between wind turbine manufacturers that now compete to obtain tenders for a new park. The structural change caused a jolt through the whole ecosystem down to suppliers and dramatically increased the competition among all players. This jolt shifted focus more toward cost reduction and project success (Andersen and Drejer 2008).

4.3.2 Competition and Internationalization

Besides the new structural situation, a rapid international market growth occurred; it attracted foreign multinational corporations with huge financial force into the ecosystem [e.g., General Electric (GE)]. These circumstances finally initiated a series of rationalizations, buyouts, and mergers to stay competitive in the wind turbine market. Eventually the number of Danish wind turbine manufacturers radically decreased to Siemens (absorbing Danregn Vindkraft A/S and Bonus Energy A/S) and Vestas (absorbing NEG Micon A/S) as the main two players in the region (Andersen and Drejer 2008).

4.4 Fourth Phase: Restructuration Phase 2006–Present

The reduction of competitors was not enough to stay competitive on the marketplace for manufacturers. Both Siemens and Vestas had to restructure their supply chain in order to run their value chain leaner and more successful. The challenge for both companies was their still almost flat supplier structure in 2006 (Andersen and Drejer 2006). Suppliers mainly delivered their parts directly to the manufacturers, which caused additional organizational work for the manufacturers (Megavind 2013).

A major change happened in the supply chain in the ecosystem during the following 6 years. The flat supply chain transformed to a tier-based supply chain structure. The tier structure brought forth the introduction of the concept of "tier one" key suppliers (Andersen and Drejer 2012).

4.4.1 Changing to an Open Supply Chain Structure: Innovation for a Global Industry

This structural development of the ecosystem led to stronger research, development, and demonstration competence and cooperation across the value chain. Furthermore, it enabled sub-suppliers to deliver to different wind turbine manufacturers and strengthen the innovation in the whole ecosystem (Megavind 2013).

This evolution has brought the industry to rotor diameters of 160 m and capacities of 9.5 MW (Renewable Energy Agency 2018). Modern wind turbines are equipped with over 100 digital sensors, which transmit real-time data on the status of the turbine; they generate 2 gigabytes per day of data and open a myriad of opportunities to analyze and optimize turbine's operations.

5 A Value Chain View of Entrepreneurial Opportunities

We now take a step back to understand how new entrants have contributed to this successful evolution, how have new technologies been introduced, and what does this mean for digital technology entrepreneurs in the wind energy ecosystem.

5.1 One Industry but Different Maturity Levels

In their annual report of 2017, the Danish Wind Industry Association highlights that market demand during the last years has led to increasing industrialized production through standardization, regulatory requirements, and supply chain development, which are clear signs for maturity in industrial processes (Megavind 2017). Several of the actors we interviewed described the steps that the industry has done toward consolidation. Director 2 highlights this maturing process in saying that:

> [. . .] over all the most important thing that is happening is that the industry is getting more and more mature. With that I mean that the focus on driving down costs and doing things more and more standardized, you know consolidation of technological platforms, consolidation of manufacturers and suppliers (Director 2).

But, at the same time, the industry has new upcoming fields such as decommissioning and blade repair, which are in an early-stage phase. The Danish Wind Industry Association states in the same report that the industry is facing challenges when it comes to wind power plant life cycle, digitalization, and emerging markets. The new markets for wind power also introduce new conditions and challenges such as variety of climates, extreme weather, transport, or complex installations to name a few (Megavind 2017). The approach to these new challenges requires still an entrepreneurial mindset, as one of the expert researchers mentioned:

> Well it was less mature than now, it is maturing, but it is still a very, very, immature industry. Basically, they start-up again with every new farm; they start-up from scratch (Researcher 3).

5.2 *A Substantial Barrier for New Entrants with Digital Technologies*

The wind industry is a field where in most cases problems have already existing solutions; new entrants, consequently, have to verify and test their novel concepts considerably more, whereas start-ups in rather novel areas are able to bring their products to market with less certification and testing processes, and have much more room for experimentation as it often happens with new technologies (Woolley 2014; Giones and Brem 2017). As the CEO of a service and transport company mentions:

> I would not start [his company] today, I think that would be almost impossible, but when we started [his company], there was basically a gap [. . .] it was not that I had years of experience, but nobody had (years of experience) at that time [. . .] but there a still new niches where nobody has started a company. I mean, we could start another company. . . (Director 1).

A more detailed analysis of the interviews suggests that actually the opportunities for new entrants have different characteristics, and entry barriers, depending on whether they fall in the development or operations part of the industry value chain.

5.3 *The Value Chain Structure Determines the Gaps for New Entrants*

The value chain for the industry in Denmark is described in Fig. 1. From left to right, it starts with sub-supplier and system supplier, which deliver to wind turbine

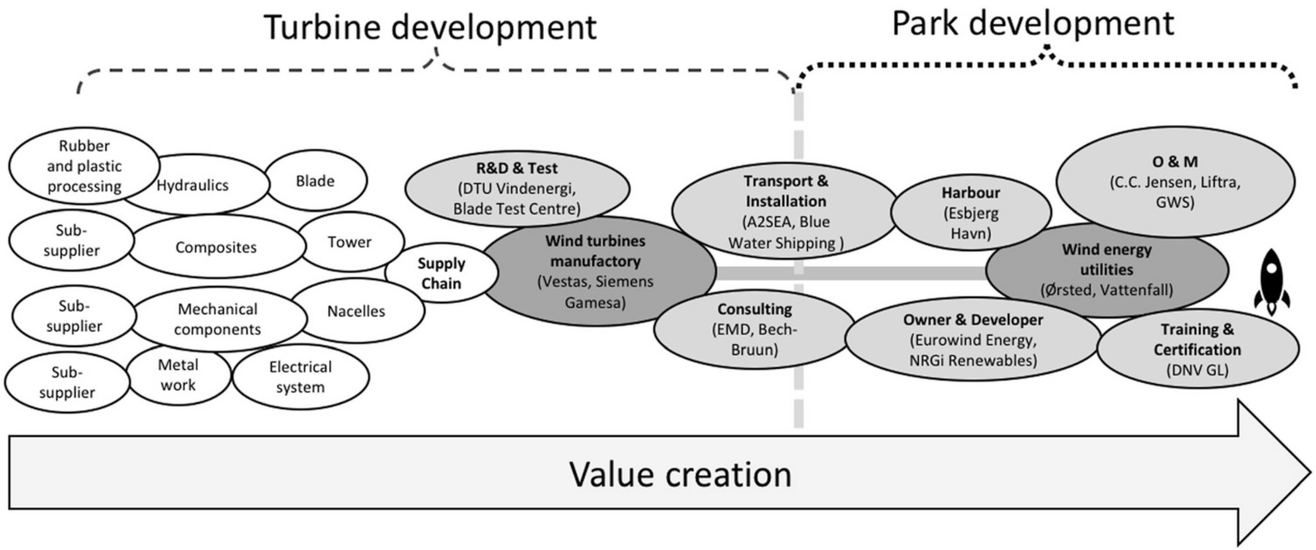

Fig. 1 Value chain of the Danish wind industry with company examples from the Danish Wind Industry Association (Danish Wind Industry Association 2017). Source: authors' own figure

manufacturers. Research and test institutions contribute to turbine development, as well. After the turbine development activities, the next major actors in the value chain are the wind energy utilities, which tender new wind parks. To build these parks, actors in transportation, installation, and consulting are required in the value chain. Local harbors facilitate the transport process from onshore to the off-shore park location and park owners monitor the process. The successful operation and maintenance of wind turbines through appropriated training and certification is the final step in the value chain (Danish Wind Industry Association 2017; Megavind 2013). The rocket icon on the right-hand side depicts the area, where we found most entrepreneurs entering into the industry value chain. Furthermore, most interviewees see this area in the value chain as highly attractive for the introduction of new digital technologies.

5.3.1 Three Major Barriers and a Surprise for New Entrants in the Turbine Development Activities

Interestingly, for an industry that historically thrived on collaboration between researchers and competitors, the development phase of their products has now become a closed process. Three major barriers have emerged for new entrants, in particular if they are completely new companies with limited resources or experience in other industrial fields.

First, there is a lack of information on where digital and non-digital innovation is needed. One interviewee highlighted this fact as follows:

> There are so many things (innovation challenges for wind turbines). The problem in all this is to identify them, and actually also for the wind turbine manufacturers to communicate them, because a part of communicating an innovation challenge includes to reveal your technology. They (innovation challenges) can be discussed when you are together with them (manufacturers) and know them, but they are not putting them out (Researcher 1).

Second, the high and mature technological level of the turbine development requires more experience and advanced research resulting in higher development costs. Additionally, as turbine development happens at the beginning of the value chain, its technological innovations strongly impact companies located in other areas of the value chain. Take for example, mechanical improvements on the nacelle's design; these changes may require new arrangement of components inside of the nacelle, adaptions of transport vehicles, adapted lifting equipment, and lastly, training of installation and service personnel. The turbine development impacts many actors and the innovations have to be coordinated across the value chain. Hence, changes in the turbine development have to be well thought out, as wind turbines have tremendous investment cost and long lifetimes. As an experienced engineer in the Danish Wind Industry Association described:

> If you take for instance the aviation industry. The blades are almost like a wing from an aero plan and the numbers are very similar to the aircraft industry. Bringing in huge components from all over the world. [. . .] when it (Wind turbine) doesn't run it costs a lot of money, but it doesn't cost lives as it does in an aircraft. But a machinery which is going to manufacture

> around 100.000 hours in its lifetime. It is very critical, it has to be very well regulated, very well controlled, and very well described. So, you have to learn a little bit from critical industries, as well (Engineer 2).

These conditions force new entrants introducing innovations in turbine development to include high warranties to cover breakdown risks. This adds financial stress to the new entrants:

> Projects get bigger and bigger [. . .] You need to have more funds, because let's say 10 years ago you could put up a warranty for let's say 5 million dollars, that would be ok. But now, you need to put up like 30 maybe 50 maybe 100 million dollars, before they let you in, they need to be sure that if anything happens you can pay (Researcher 3).

Third, the industry life cycle (Klepper 1997) determines the opportunity window for new digital innovations. Turbine developers only change their development platforms for a new turbine after several years when there are enough potential innovation gains that make it worth changing the whole platform. These circumstances put extra pressure on the new entrants exploring the potential of a new technological innovation; the entrepreneur has to pace their tech development to the opportunity window in the industry. As an expert researcher described:

> They are not thinking long-term. They are only thinking one project at a time, because they do not know if they get the next projects, so why invest time and resources in better collaboration, better interface management and so on (Researcher 3).

Additionally, for successful market entry, new suppliers have to either address an urgent need caused by an unexpected problem in the industry or synchronize their solution with a new generation that uses a different manufacturing platform. The interview with the Danish Wind Industry Association highlights the importance of this issue:

> You have to have the first customer who is going to pay for the product and make the test [. . .] So there has to be a problem or you have to offer your product when they start with a new manufacturing platform (Engineer 2).

Contrary to our expectations, the degree of digital innovation in turbine development and manufacturing seems to be rather low. This is explained by the focus on increasing the power generated by wind turbines, instead of aiming for efficiency gains with digital technologies. In this sense, the wind industry could be another context where digital entrepreneurs could replicate successes in other similar industries such as the automotive industry (Woolley 2010). But this is not happening yet. As one of the researchers pointed out:

> When you talk about manufacturing in Siemens and Vestas, then it (the digital innovation of manufacturers) will be like any other business in the production side and I don't think that will be much different than Grundfos and Danfoss and other industrial manufacturers (Researcher 3).

5.3.2 Opportunities in the Operation and Maintenance Activities of the Value Chain

While there is limited entrepreneurial activity in turbine development, it is actually downstream the value chain where we see more activity. In the "park development" activities described in Fig. 1, there have been several new entrants, as reported by one of the experts in the field:

> They (turbine manufacturers) do not want to take any risk. I think that is a barrier for new developers, especially if it is (related to) technology. It is easier (to enter) in the operations, service and maintenance areas (Researcher 3).

The park development fundamentally consists of services-related work. Service activities have fewer risks than turbine development; in case of errors you only have to bear with the running costs of the services. The service and maintenance activities have seen more new players than the turbine development activities. Engineer 2 points out that:

> It is very much depending on what do you bring in the market, it is typically in operation and maintenance where they grow fast. Growth is very (dependent on) the industry. It is typically (related to) the main components, when you supply control systems you grow with your customer. But [. . .] exponential growth [. . .] is related to manpower, that means operation and maintenances, it is related to (introducing) disruptive technology (Engineer 2).

The term of disruptive technologies is used as a synonym for digital technologies, as they are capable of restructuring the service and maintenance work by making manpower partly redundant and allow for new business models. Furthermore, the field of innovation of park development is more clearly defined than the non-visible innovation challenges in turbine development. According to several industry sources, 50% of the operating expenditures are caused by unscheduled maintenance. This fact is well known and energy utilities nudge for innovation to reduce this number as soon as possible.

5.3.3 Where Did New Entrants Go in the Wind Industry?

The search on start-ups within the Danish wind industry, using information registered at the large start-up repository Crunchbase (crunchbase.com), gives evidence of the limited number of new entrants in the industry in the last 10 years. It is quite significant that 8 out of the 10 founded start-ups are working within the operation and maintenance area, as Table 2 shows.

Companies in operation and maintenance have also understood that digital innovation can bring new game-changing solutions that can reduce costs, downtimes, and risk. The Danish Wind Industry Association believes that digitalization is capable of bringing up new ways for rethinking the life cycle of wind energy parks. Thereby, a complex web of data should connect planning, design, manufacturing, transportation, operation, maintenance, and decommission (Megavind 2017; Brink et al. 2016).

Actors in the industry are aware of the data collection easiness using digital technologies; however, the perception is that the human experience is still required to analyze the data output. Director 2 argues that:

> You still need to do an evaluation of what has been filmed by the drone and you have to decide on the action that has to be done (Director 2).

Further challenges are seen to make the most of big data or artificial intelligence solutions for the industry. For example, the problem of comparability of data emerged:

> the digital part, of course, plays a role, at the moment it is apples and bananas because you have a lot of data, but it is from different wind turbines, it is from different turbine sizes. So, you have a lot of data which is not comparable, because the wind turbine has grown in size and different types and whatever. So, it is limited how much you can utilize the data (Researcher 2).

5.4 *The Future of the Industrial Innovation Ecosystem*

The predominant position of Denmark as a wind energy hub has changed over the last 20 years. Interviews revealed that the wind energy ecosystem in Denmark is not a key global gatekeeper for new entrants. We expected that regional proximity would be a key factor to attract entrepreneurs and innovation to the industry (Boschma 2005). But the wind energy industry is demand driven, meaning their sites and actors are always moving to the geographic location where "*the support machine is running*" (Director 2). Furthermore, the pioneer's positions are lying rather with the Danes and their knowledge than in the region, as they keep their positions at the top of the leading companies. Researcher 2 adds that:

> It (the advantage) is that they still have the education, the training and the network going on and the Danish people are very good at that (Researcher 2).

Therefore, it appears that the knowledge that has contributed to build the innovation ecosystem is much more movable than we would have expected; this would suggest a close dependence between where the knowledge is rewarded and where growth and strategic renewal occur (Agarwal et al. 2010).

Nevertheless, the localized social and human capital still has a big influence on the successful entry of new entrants. We use the case of one of the companies' interviews to illustrate how digital technology entrepreneurs interact with the established industrial ecosystem. The company (name not disclosed due to anonymity request) is developing a new digital service solution for wind turbines using a robotic aid. Both cofounders are very experienced as they have worked in the wind industry for several years (thus we are in a knowledge spillover situation). They are well aware of the entrance barriers that are prevailing in the ecosystem. As a safety, both cofounders agreed on three milestones, which had to be achieved before they would establish the company and further develop their technology: (1) a proof of technological feasibility, (2) a first customer, and (3) financial support. These three milestones also reflect the entry barriers, which were described by other interviewees. It was only after overcoming each of these milestones that the cofounders officially started their successful company:

> I would like to say we had three milestones we needed to accomplish before we could start the company [. . .] The first thing was that we ourselves wanted to belief in the technology before working [. . .] So, step number one was we needed to test the technology or subcomponents of the technology to an extent where we belief ourselves that it could be done. Step number two were to get a player in the market to belief in the product to an extent where they were willing to allow us to test on the product free of charge. [. . .] somebody else also need to belief in the product, that either be a wind turbine owner or a windfarm producer [. . .]. The third one, we wanted that somebody who thinks commercially (with a business mindset) should also believe in it. This was formulated as somebody else also needed to put in some money into the project (Director 3).

As a result, we see how the industry consolidation has also affected the entry strategies in the downstream operations of the value chain. On the other hand, the core technology development activities related to the new wind turbines have been kept in-house and subject to an increasing pressure with shorter development times and lower overall production costs.

While the turbine development activities are still the most knowledge-intensive activities, the areas where new digital technologies are having a stronger presence, as well as new entrants, is in the last activities in the value creation process. The challenge for the industrial ecosystem in the Danish region is that these last activities are mostly performed where the wind turbines are installed and maintained, making them more likely to be offered by local players.

6 Implications for Research and Practice

Going back to our starting point, we expected to see an interaction between the digital technologies entrepreneurial ecosystem and the wind industry innovation ecosystem that could contribute to the present and future growth of the industry in Denmark. What we have observed instead is an industry that is closing part of its value chain and shifting toward global competition. Instead of seeing a process of strategic entrepreneurship by the leading actors in the ecosystem, what our results suggest is that they have sustained their focus on the technology development leaving open the operation and service areas of their products.

In our research, we have observed that while the entry barriers have reduced the number of new competitors in the turbine development, it has also made it a more cost-driven market. It has been in park development and maintenance where entrepreneurs (as new entrants) with novel technological solutions have found opportunities to introduce digital and non-digital innovations and start servicing customers.

Furthermore, several of the data sources we have reviewed suggest that the shift toward a service orientation could be the main driver of growth in the whole wind energy industry in Denmark. As one of the expert researchers in the industry mentioned:

> If we look at Vestas, their services business is increasing rapidly and so is Siemens', because, think about it, in a decade or so we will not need any new projects, we only need to reinstall power plants, therefore we will see (more often) the business case of the service provider (Researcher 3).

However, an improvement of wind parks also implies a development of the turbine technology in order to reduce breakdowns and increase efficiency or services related to the decommissioning of the park. This will have an impact on the mix of products and services of the industrial players in the region.

6.1 Keeping the Innovation and Entrepreneurship in the Region

In practical terms, our findings suggest the need to act in order to stimulate digital innovation in the industry. To improve the innovation dynamics for turbine development, the current high entrance barriers, including funding and testing, should decrease. Advanced research and test facilities in the innovation ecosystem could lower entrance barriers, where new digital technology innovations could be tested and developed on major platforms to attract clients more easily. This could be similar to concepts being put in practice in emerging industries, where entrepreneurs can test new technology applications in testbeds (Mulgan 2017); such arrangements also support the different maturity levels (including standards and regulation) required for innovative experimentation and industrialized production.

A concerning finding is that the region that has benefited the most during the emergence of the industry might not be able to keep a relevant position in the future. Our results show that the industry location is rather demand driven, "*due to scale we (Denmark) cannot be in the forefront anymore*" (Researcher 3), as other regions will come up with much higher wind energy demand prospects (both onshore and offshore). Therefore, it is important to strengthen the research and development of wind turbines, so major wind turbine actors keep their main research and development actives in the Danish innovation ecosystem. In other words:

> I think Denmark could still be the hub and the pioneer due to [the fact] that we have Vestas and Siemens. But the issue for Denmark is that we are not so big, so we cannot install so many power plants (Researcher 3).

A valuable insight for innovation policy makers and institutions in the region is that the connection between digital technologies entrepreneurs and the industrial ecosystem does not occur automatically. Our findings suggest the need for intermediaries that facilitate the connection between researchers, entrepreneurs, and established industrial players (Howells 2006; Clayton et al. 2018). We have seen some positive anomalies, for example, the case of Vaavud, a crowdsourced weather service, which aims to provide valuable insights for the wind turbine operators, but these have been isolated success cases instead of a continuum of new spin-offs or start-ups.

In a nutshell, the entrepreneurial ecosystem for digital innovation in wind energy has the potential to increase to the level it has reached in other industries, but this might only happen if the knowledge is rewarded, if entrepreneurs' experiment with new technological applications, and if intermediaries facilitate the connection between the emerging and consolidated ecosystems.

7 Limitations and Further Research

Our results open the door to further research streams on the topic and are not absent of several limitations. First, we have been exploring a rather emergent phenomenon; only now the large industrial players are starting to adopt drones, AI, IoT, VR, or Blockchain or other digital technologies. Plus, some of these activities are conducted in secrecy as they are seen as future competitiveness levers. Therefore, the low levels of activity observed can be attributed to the phenomenon being still at an early stage. It will be important to revise, with a longitudinal view, how it evolves in the coming years as digital technologies are introduced in more mature industries that generate use cases that stimulate more entrepreneurs and increase interest across the Danish wind energy ecosystem.

Second, we tapped on the growing literature on entrepreneurial and innovation ecosystems; our results suggest that there are further opportunities in this field. For example, we could only identify that the ecosystem evolution shifted as the industry consolidated, and it actually almost split into two separate innovation ecosystems: turbine manufacturing and wind park development and maintenance. This had implications for new entrants and for the innovation dynamics; this promises to be an interesting research area to analyze and theorize on the evolution and development of innovation ecosystems, for instance, reconnecting ecosystems with biology evolution theories (McMullen 2018).

Finally, this research opens up further interesting opportunities to study how innovation ecosystems mature and when (and how) they benefit from the activity in emerging entrepreneurial ecosystems in the region. We could only report on a short historical account and recent entrants introducing digital technologies. This is an area that needs further research, as it promises to hold valuable insights for innovation policy makers and industrial players that want to contribute to their region's growth and development.

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Virtual Reality as a Digital Learning Tool in Entrepreneurship: How Virtual Environments Help Entrepreneurs Give More Charismatic Investor Pitches

Oliver Niebuhr and Silke Tegtmeier

Abstract This chapter deals with the entrepreneurial key element of the "investor pitch" and examines by means of a combination of speech-production and perception experiments if and to what extent the acoustic parameters of a charismatic tone of voice can be improved by rehearsing a pitch in a virtual presentation setting in comparison to a traditional setting in which speakers rehearse their pitch alone in a quiet room. About 5000 measurements were taken from the elicited investor pitches, and the acoustic results were cross-validated by 31 listeners who judged excerpts of all pitches in terms of perceived speaker charisma. On this basis, this chapter provides empirical evidence that the traditional rehearsal setting degrades the charismatic tone of voice of a speaker with each new repetition of the investor pitch. Rehearsing in a virtual reality (VR) environment, on the other hand, counteracts this erosion effect and even results in a gradual improvement of the speaker's charismatic tone of voice. Initial findings also indicate that this positive VR effect persists when speakers return from the virtual to the traditional rehearsal setting. The results are discussed with respect to their implications for practitioners and for further research and development of digital learning technologies in entrepreneurship education.

Keywords Virtual reality · Investor pitch · Rhetoric · Prosody · Charisma · Digital learning

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1 Background and Assumptions

It is indisputable that entrepreneurship represents an important pillar for national economies and makes a significant contribution to economic growth and social prosperity (Acs et al. 2005; Audretsch et al. 2006; Bertoni et al. 2011). Since the 1980s, i.e., with the rise of computers, digital (mobile) communication, and Asian markets, there has been a shift from a purely "managed economy" to an "entrepreneurial economy" (Thurik 2009). Unlike the former, the latter relies less on the increasingly efficient mass production of a few large companies. Instead, an entrepreneurial economy has its focus on knowledge, innovation, and customized products or services that are produced by a large range of smaller start-up companies (Thurik 2009). However, in order for start-ups to grow and establish themselves in the market, their inexperienced and often young entrepreneurs depend on investor capital, for example, from venture capitalists, business angels, or private individuals who make their investments through crowdfunding campaigns on the Internet.

The positive effect of investor capital on the survival and growth prospects of start-ups has been well documented in many studies and for many countries, especially for technology start-ups (e.g., Colombo and Grilli 2010; Bertoni et al. 2011 for Italy and Hadley et al. for the USA). The flip side of this coin was summarized by Cunningham (2010: 1) as follows: "When an entrepreneur cannot secure funding or other necessary resources, often the business cannot move forward and essentially dies." Furthermore, attracting investors means not only that start-ups can close their inherent "funding gap" (Dempwolf et al. 2014: 6). Investors also contribute strategic and operational know-how and bring their business networks and social capital to the young companies (Borgefors and Lahlou 2017; Hadley et al. 2018). In addition, research shows a positive upward spiral in which initial investments act as a seal of quality which, in turn, allows entrepreneurs to attract further funding more quickly and easily (Chan and Fei 2015).

Therefore, fund-raising activities are among the core tasks of entrepreneurs, next to legitimizing and networking activities (Kang et al. 2015; Fisher et al. 2017). These fund-raising activities include writing business plans and short executive summaries. However, another important and perhaps *the* most important fund-raising activity is the investor pitch. An investor pitch is a fairly conventionalized form of portraying a start-up in a concise oral presentation. Pitches are typically supported by PowerPoint slides and give potential investors an overview of the entrepreneurial team, opportunity, solution, competition, business model, and, ultimately, of "the ask," i.e., of the contribution that investors shall make to the new business. The ultimate goal of each pitch is to persuade investors to invest in the start-up. However, this is not an easy task. Not only has the entrepreneur to overcome the risk threshold of an investor. Investment capital is generally a very limited resource. Hence, every start-up is in a tough competition for this resource with many other start-ups. This tough competition manifests itself most clearly in big pitching contests or start-up competitions. Many hundreds of such events take place every year all over the world.

Pitches are the first step on the path to investor funding. Moreover, pitches are often the setting in which entrepreneurs and potential investors meet each other for the first time (Clark 2008). Without a successful first step, there is no second one and, thus, no investment. In consequence, the investor pitch is nothing less than a make-or-break issue for a start-up; and as the entire start-up process "rides on the success of the pitch in engaging investors, this first step received a substantial amount of attention in determining what factors are considered important for creating a "winning" pitch" (Cunningham 2010: 1; see also Sherry 1988).

Prior to the investor pitch, potential investors have typically read neither the business plan nor the executive summary; and still they decide within a few moments, i.e., long before the entrepreneur has had the chance to put all the information and arguments on the table, whether or not they are basically willing to invest. Therefore, the strongest weapon of the entrepreneur in the fight for investor capital is his or her power of persuasion based on what has been termed an immediate "emotional contagion" (Fox Cabane 2012). Persuasion and "emotional contagion" are researched in many scientific disciplines under the keyword of "charisma." As was recently stated by Flanigan (2013: 217): "Modern definitions of charisma [. . .] reference exceptional abilities to persuade and motivate."

Charisma arises from two elements. The first one is the so-called delivery, i.e., the nonverbal performance of a speaker during an oral presentation. The second element is the choice of words (Antonakis et al. 2011). Studies show that the nonverbal performance of a speaker and in particular his or her tone of voice play a greater role in charisma perception than the choice of words (Holladay and Coombs 1994; Shea and Howell 1999; Awamleh and Gardner 1999; Fox Cabane 2012; Scherer et al. 2012; Chen et al. 2014). So, having a particularly charismatic tone of voice in an investor pitch can give an entrepreneur a decisive advantage over other entrepreneurs in the struggle for investor capital. Empirical studies also show that crowdfunding campaigns are significantly more successful and that the advertised products or services are perceived to be more worthy and have a higher quality, if they are pitched more charismatically (Gélinas-Chebat et al. 1996; Davis et al. 2017). In addition, charismatic speakers have an easier time building relationships with stakeholders (Pentland 2008).

But what is a charismatic tone of voice and how can it be trained? Current charisma coaches and rhetoric guidebooks can only provide incomplete or vague answers to these questions, because, in the words of Cunningham (2010: 1), "the vast majority of available knowledge hovers in the intuitive realm." Therefore, in order to make full use of state-of-the-art experimental methods and technologies, we started PERCY. PERCY (Persuasiveness and Creativity) is a line of research and practice on acoustic charisma profiling and training that puts, with a focus on entrepreneurship, the analysis and treatment of a speaker's tone of voice on a new innovative footing (Niebuhr et al. 2017). First, PERCY is able to precisely quantify and objectively evaluate a speaker's tone of voice in that it links traditional rhetoric terms like "animated," "clear," and "fluent" (cf. Fox Cabane 2012) to parameter classes and levels of the speaker's acoustic speech signal. As we will outline in more detail in Sect. 3, perceiving a speaker as charismatic relates to acoustic correlates of tempo, pitch, phrasing, pausing, and loudness, as well as to how much speech a speaker produces, for example, how many syllables she or he utters in total.

Entrepreneurs are no professional speakers like newsreaders, actors, or masters of ceremony. However, such a degree of professionalism would be required to consciously control one's tone of voice and sound more charismatically, especially in stressful situations. So how can we shift the tone of voice of entrepreneurs quickly and effectively in a more favorable (i.e., more charismatic) direction? The best way to do this is to use methods that suppress an unfavorable tone of voice and/or spontaneously trigger a more charismatic tone of voice. Both must happen so consistently that the new way of speaking has sufficient time to consolidate and become a routine matter for the entrepreneur.

Facing this challenge, a second goal of PERCY is to test and introduce digital learning technologies that help entrepreneurs find the right charismatic tone of voice and master it effectively and with high proficiency. In other words, our acoustic charisma profiling and training represents a new interface between digital technologies on the one hand and fundamental entrepreneurial skills on the other.

This chapter summarizes the results of a proof-of-concept study that focuses on one aspect of this interface: practicing investor-pitch presentations in a virtual reality (VR) environment. Our overarching research question is whether this way of digitally supported learning is effective in stimulating and consolidating a charismatic tone of voice. Besides making speakers face and eventually overcome their anxiety to give public speeches (North et al. 1998; Pertaub et al. 2002), we assume VR technology to be useful for charismatic speech training in three ways.

Assumption 1 VR technology helps speakers switch from presenting in a sterile text-oriented "memorization mode" to presenting in an expressive, audience-oriented "communication mode." More specifically, compared to a rehearsal of an investor pitch alone in a silent room, the VR environment puts speakers in front of virtual people and, thus, makes them adopt a dialogue speaking style. A dialogue speaking style is inherently more charismatic than a monologue speaking style, and, on top of that, intending to actually get a message across to somebody is obviously a prerequisite for showing nonverbal charismatic behavior at all.

Assumption 2 Based on the first point, the VR environment could prevent that, after some rounds of repetition, practicing the investor pitch becomes a mere myo-mechanical exercise in which the energy put into one's speech wears off and boredom creeps in. Such an "erosion effect" was already observed by Niebuhr and Kohtz (2013) for people who read long lists of similarly constructed and/or repeatedly occurring isolated sentences in a laboratory speech-production experiment. Besides pronunciation, the speech erosion particularly strongly affects a speaker's tone of voice and in this way undermines charisma perception.

Assumption 3 If speakers show the same context-adjusted speaking behavior in VR environments as in real environments, then they will speak louder, at a higher pitch level and with a fuller, stronger voice quality the larger the VR room gets and the further away the speaker is from the audience. These changes, which represent an increase in the speaker's so-called vocal effort (Traunmüller and Eriksson 2000), go in the direction of a charismatic tone of voice. On this basis, we assume that the VR environment spontaneously (just by means of a speaker's contextual adaptation) stimulates basic characteristics of a more charismatic tone of voice.

2 Study Design and Expectations

We use an experimental approach to test Assumptions 1–3. Three presentation conditions were created, one without VR and two with VR; see Fig. 1. Condition [i] represents the traditional rehearsal condition in the form of a self-directed talking-through of a slide deck (baseline). In condition [ii], the rehearsing speaker presents the slide deck to a small VR audience that sits close to him or her in a small meeting room. Condition [iii] is like [ii], except that the slide deck is presented to a large VR audience that sits in large keynote hall further away from the rehearsing speaker. Two speech-production experiments were carried out on this basis. Each experiment included two groups of speakers, a control group and a test group.

Experiment 1 tested Assumptions 1–2, i.e., whether a VR audience simulation supports acoustic cues to charisma by making speakers adopt a dialogue rather than a monologue speaking style and by reducing the speech-erosion effect. To that end, test group speakers pitched in VR condition [iii] and control group speakers in condition [i] without VR. In each condition, the investor-pitch presentation was rehearsed four times in a row. Talking through a presentation multiple times in direct succession in a monotonous context corresponds to the typical rehearsal situation

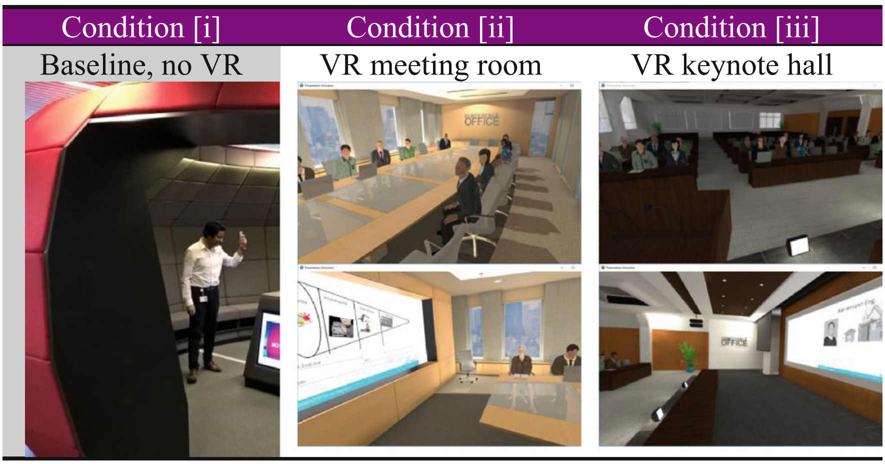

Fig. 1 Self-directed talking-through of a slide deck (baseline, left) and the two VR presentation conditions with a small (middle) and a large (right) speaker-listener distance. Left: authors' own photograph. Middle and right: authors' own screenshots of the "presentation simulator" software (http://www.presentationsimulator.com/presentation-software/)

that probably all readers have found themselves in many times already when they prepared for a talk. Thus, this is a representative everyday setting. Moreover, it provides the breeding ground for the speech-erosion effect.

If the speech behavior under these circumstances is in accord with Assumptions 1–2, then the following results can be expected for Experiment 1. Compared to the control group presentations under condition [i] without VR, the test group presentations under condition [iii] with VR will show (clearer) acoustic characteristics of dialogue speech. Furthermore, comparing the four rounds of repetition will reveal that, compared to control group speakers, test group speakers will show no or fewer signs of speech erosion in their tone-of-voice features.

Experiment 2 provides further empirical evidence on Assumptions 1–2 and, in addition, addresses Assumption 3, i.e., whether or not VR technology causes a spontaneous adjustment of vocal effort to the speaker-listener distance in the presentation setting. Accordingly, test group speakers went through the rehearsal conditions of Fig. 1 in the sequence [i]–[ii]–[iii]–[i] or [i]–[iii]–[ii]–[i] (the order of conditions [ii] and [iii] was balanced across the test group speakers), whereas control group speakers went through condition [i] four times in a row, just like in Experiment 1.

If the speech behavior elicited in these rehearsal settings is in accord with Assumption 3, then we can expect the following. The test group speakers' acoustic speech signals will show an increase in vocal effort from the baseline condition [i] to each of the two VR conditions. Among the two VR conditions, there will be a further increase in vocal effort from the meeting-room VR condition [ii] (with a small speaker-listener distance) to the keynote-hall VR condition [iii] (with a large speaker-listener distance).

Beyond testing these assumption-based expectations, Experiment 2 also allows comparing the two baseline conditions [i] from the beginning and end of the test groups' quadripartite presentation sequence. This comparison will provide initial indications on the extent to which the expected charisma-supporting effect of a VR audience simulation is a lasting effect that is carried over into a presentation setting without VR. Note that our condition [i] probably represents an extreme—i.e., maximally unfavorable—test case for such a carryover effect. Firstly, this is because speakers still rehearse rather than actually pitch and, therefore, have no external incentive to apply to the final condition [i] what they did, felt, and learned in the two preceding VR conditions [ii] and [iii]. Secondly, the audience-free condition [i] differs strongly from the audience-based VR conditions [ii] and [iii], and it is well known that any transfer of learning is most pronounced and consistent when the learning condition is similar to the application condition (Barnard 2005). So, if we find a carryover effect from conditions [ii] and [iii] to the initial condition [i] under these unfavorable circumstances, then it is likely that this effect is even stronger in an actual presentation setting in front of a real audience.

The two speech-production experiments were concluded by a speech-perception experiment, i.e., Experiment 3, in which listeners rated on a scale how much the speakers of Experiment 2 got better or worse in their charismatic tone of voice from one rehearsal condition to the other. Short speech sections were extracted to that end from the individual investor-pitch rehearsals of Experiment 2 and arranged in pairs of stimuli for perceptual comparison. Based on the assumption that VR-based investor-pitch presentation training has a beneficial effect on perceived charisma, we expect the rehearsals made in baseline condition [i] to score lower in terms of perceived speaker charisma than the rehearsals made in VR conditions [ii] and [iii]. Moreover, among the latter two VR conditions, we expect condition [ii] speakers to score lower than condition [iii] speakers. Finally, with respect to the erosion effect, we expect control group speakers, who practiced their investor pitch repeatedly in the condition [i] setting, to score lower in their last than in their first repetition. Test group speakers, on the other hand, should score higher in their last than in their first repetition of condition [i].

3 Acoustic Parameters

The selection of acoustic parameters was guided by Assumptions 1–3. That is, the selected parameters had to represent the key features of (1) monologue versus dialogue speech, (2) speech erosion, and (3) vocal effort. Below, we motivate the parameter selection for each of the three phenomena on the basis of empirical evidence. In addition, we specify how each parameter is linked to differences in perceived speaker charisma.

Studies that specifically examined the differences between the tone of voice in monologue and dialogue settings are scarce (Niebuhr et al. 2010; Görs and Niebuhr 2012). But since read speech has been mainly investigated in monologues and spontaneous speech in dialogues, we can assume that some of the acoustic differences characterizing read speech and spontaneous speech are connected to the presence of an interlocutor. Read speech and spontaneous speech both constitute a spectrum of styles depending on medium, preparation, and the amount of interaction (Laan 1997; Goldman et al. 2014). Nevertheless, there are recurring acoustic features associated with the differences between spontaneous and read speech. Compared to read-speech monologues, spontaneous-speech dialogues show, for example, a lower speaking rate (Levin et al. 1982; Niebuhr et al. 2010; Hirschberg 2000; Mixdorff and Pfitzinger 2005) as well as a higher level and a larger range of the fundamental frequency,[1] i.e., F0 (Levin et al. 1982; Laan 1997; Dellwo et al. 2015; Wagner and Windmann 2016). Furthermore, more speech is produced in a dialogue than in a monologue setting.

Regarding the speech-erosion effect, Niebuhr and Kohtz (2013) found that the monotony of traditional laboratory speech-elicitation tasks (e.g., long lists to isolated

[1]The fundamental frequency, or F0, specifies the number of vocal-fold vibrations per second and is the major acoustic correlate of the perceived pitch in a speaker's voice (Johnson 2012; Niebuhr et al. 2019); we will use the term F0 henceforth in order to refer to perceived voice pitch in speech, also to avoid any misunderstandings with the technical term "pitch" in entrepreneurship.

sentences) makes speakers increase their speaking rate,[2] lower their F0 level, and narrow their F0 range. That is, speakers sound faster, lower-pitched, and melodically more monotonous. A further integral feature of the erosion effect is that speakers lose their focus on the communicative task. Therefore, speech production becomes overall more disfluent.

Research on vocal effort revealed that speakers increase their intensity (i.e., perceived loudness) level[3] and their F0 level when the speaker-listener distance is larger and the vocal effort higher (Traunmüller and Eriksson 2000). A higher vocal effort also includes changes in a speaker's voice quality. These changes can be measured in terms of how the acoustic energy generated by the speaker's vocal folds is distributed across the speech signal's frequency range. Simply speaking, a strong effortful voice maintains a similarly high acoustic-energy level from F0 up to spectral frequencies of about 5 kHz, whereas a thinner and less effortful voice starts losing acoustic energy after 2 kHz and additionally gets airier toward and beyond spectral frequencies of about 5 kHz due to air turbulences created at the weakly compressed vocal folds. We use two established parameters to measure voice quality: the Hammarberg index and the harmonics-to-noise ratio (HNR). The Hammarberg index represents the acoustic-energy difference between the two spectral-frequency regions of 0–2 kHz and 2–5 kHz. The HNR parameter quantifies (in dB) how much of the overall acoustic energy of the speaker's voice is air turbulence compared to regular voicing. A stronger, fuller, and more effortful voice manifests itself in lower values of the Hammarberg index and higher values of HNR (Huang et al. 1996; Liénard and Di Benedetto 1999).

Table 1 summarizes the selected acoustic parameters and specifies how the study's expectations described in Sect. 2 translate into directions of parameter change. Additionally, Table 1 shows that the acoustic characteristics of a charismatic tone of voice run against the speech-erosion effect (Experiments 1 + 2), but are supported by the expected differences between the VR and baseline conditions (Experiment 1) as well as by the expected increase in vocal effort from VR conditions [ii] to [iii] (Experiment 2).

As for speaker charisma, investor pitches presented with a more charismatic tone of voice are characterized acoustically by a higher F0 level, an extended F0 range, and a higher intensity level. Presenting more charismatically also means producing more speech in a less disfluent fashion and at a moderate (esp. not too fast) speaking rate. The quality of the speaker's voice should be characterized by a lower Hammarberg index and a higher HNR, just like under increased vocal effort (Strangert and Gustafson 2008; Rosenberg and Hirschberg 2009; Signorello et al. 2012; D'Errico et al. 2013; Niebuhr et al. 2016a, b, 2018; Mixdorff et al. 2018).

[2]The speaking rate is acoustically estimated in terms of how many syllables a speaker produces per second (syl/s).

[3]Intensity is a widespread term in the phonetic sciences for the overall acoustic energy level. It is measured as the root mean square (RMS), i.e., the integrated sound pressure levels of a (speech) signal over a given time window. RMS intensity is specified in decibels or dB (Johnson 2012).

Table 1 The eight parameters included in the production experiments 1 and 2 as well as their expected changes and relations of the acoustic characteristics of charismatic speech

Acoustic-signal parameter	Measured in	Expected diff. VR conditions versus baseline	Expected effect of sp. erosion	Expected diff. VR conditions [ii] versus [iii]	Characteristics of more relative to less charismatic speech
Total number of syllables	Absolute numbers	↑			↑
Total number of disfluencies	Absolute numbers		↑		↓
Speaking rate	Syllables per sec. (syl/s)	↓	↑		↓ (if not too low)
F0 level	Hertz (Hz)	↑	↓	↑	↑
F0 range	Semitones (st)	↑	↓		↑
Intensity level	dB (RMS)			↑	↑
Harm.-to-Noise Ratio	dB (HNR)			↑	↑
Hammarberg index	dB (0–2/2–5)			↓	↓

Source: authors' own table

4 Experiment 1

4.1 Participants

Twelve males of the Innovation-and-Business M.Sc. program at the University of Southern Denmark (SDU), Sønderborg, participated in Experiment 1. The average age was 22.6 years. They were all L2 speakers of English at the top proficiency levels C1 or C2 (according to SDU-internal recruitment tests). Furthermore, they all had some investor-pitching experience and stated to feel comfortable in public-speaking scenarios. Thus, anxiety of public speaking was excluded as a confounding factor in our experiment.

Note that we deliberately restricted our sample to male speakers for several reasons. First, regardless of the political and social implications (e.g., Brooks et al. 2014) and a slowly changing situation (Levie et al. 2014), male entrepreneurs still outnumber female entrepreneurs, and our sample takes this fact into account. That is, focusing on males is less representative for the society, but more representative for the population of entrepreneurs within the society. Second, due to the fundamental anatomical and physiological differences in the speech production of male and female speakers (cf. Simpson 2009; Pépiot 2014), it would not have been possible to simply pool the acoustic measurements of male and female speakers. While some measurements (like F0) are relatively easy to normalize for differences in speaker sex, others (like speaking rate, voice quality, and intensity) are not. Therefore, it would have been necessary to form subsamples of male and female speakers and analyze their data separately from each other. Apart from the logistical problems that this subsample formation would have caused, our participant pool at SDU would have been too small to recruit a substantial number of speakers of both sexes. Third, despite differences in the social behavior of men and women (Caballo et al. 2014) in virtual environments (e.g., Wieser et al. 2010) and public-speaking situations (Brooks et al. 2014; Balachandra et al. 2013; Novák-Tót et al. 2017), the behavioral differences we investigate here relate to basic cognitive mechanisms that are acquired in early childhood and concern listener orientation (dialogue vs. monologue), motivation and habituation (speech erosion), and a distance-directed control of actions. There is no plausible reason to assume that behavioral differences emerging from such basic cognitive mechanisms could be sex-specific; neither are there any empirical indications for such an assumption. For this reason, although this study is on males only, we are confident that the results we obtain here will—at least in qualitative terms—generalize to female speakers as well.

4.2 Procedure

The 12 participants were randomly assigned to two equally large groups: the control group and the VR test group. The six participants in each group were instructed to prepare a so-called "elevator pitch" based on a set of three given PowerPoint slides. As is displayed in Fig. 2, the slides showcased a new biotech filter that can sustainably improve air quality in smog-threatened cities.

An "elevator pitch" is a special type of investor pitch. It is "is a concise, carefully planned, and well-practiced description of your company that your mother should be able to understand in the time it would take to ride up an elevator."[4] Thus, unlike other investor pitches, elevator pitches are typically much shorter, focus very narrowly on either the idea or the business model, and remain at a very simple, low level of description. The elevator pitch we created was about 2–3 min long, which is longer than a prototypical elevator pitch (about 1 min), but still within the common time frame of elevator pitches (Denning and Dew 2012).

All participants had learned to develop and hold such persuasive elevator pitches as part of their studies or professional duties, and, on this basis, they were given about 5 min time (in a separate silent lecture room) to familiarize themselves with the slide deck that was handed out to them. After the familiarization phase, the members of the control and test group were individually instructed to practice the elevator pitch four times in a row, with the aim to be able to present it afterward in front of an investor jury.

Participants of the control group were asked to do this rehearsal aloud, while imagining to address real listeners and seek their support for the pitched idea. The

[4]Robert Pagliarini, MIT Blossoms: https://blossoms.mit.edu/sites/default/files/video/download/The-Art-of-the-Elevator-Pitch.pdf

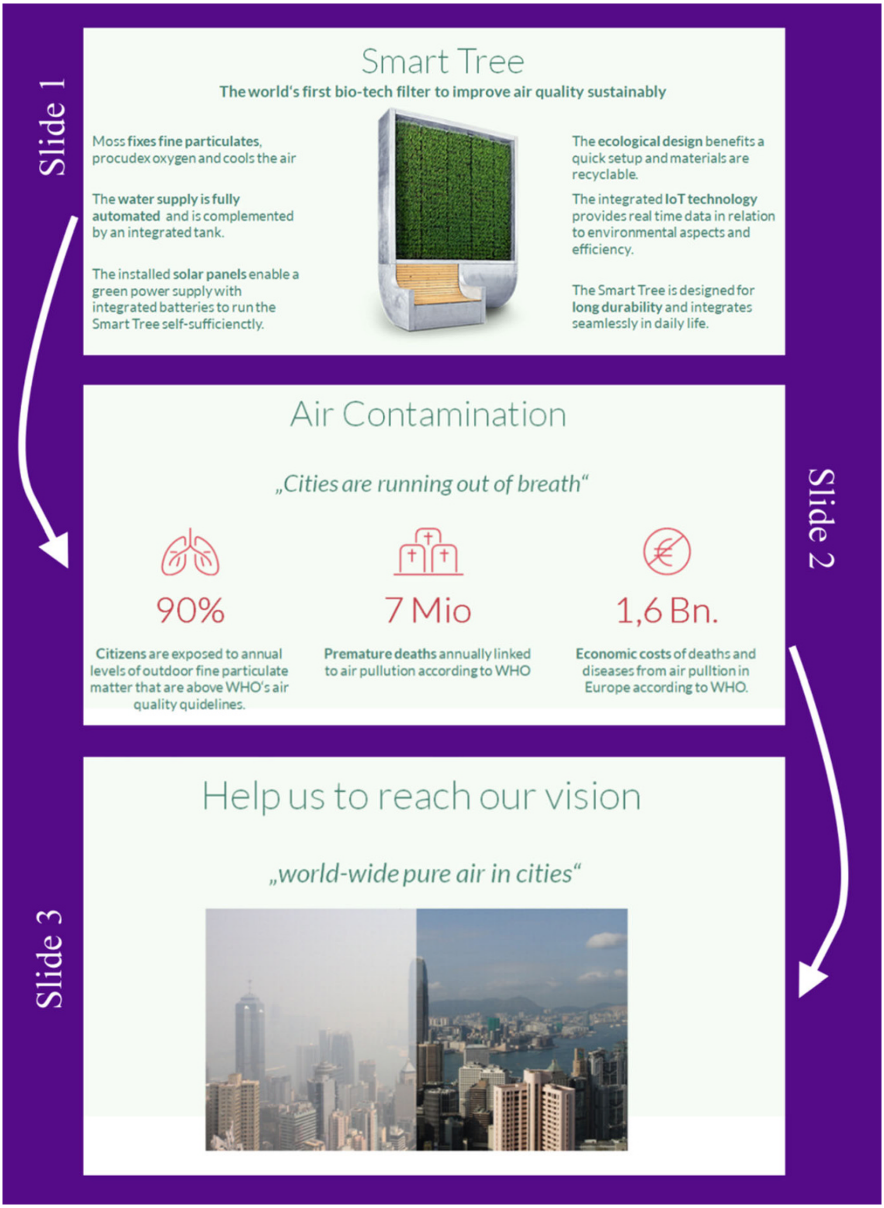

Fig. 2 PPT slides used as basis for the elicitation of the speaker's elevator pitch. Source: authors' own PPT slides; slide #3 shows an air pollution picture of Hong Kong, used under CC BY 3.0 license from Wikipedia (en.wikipedia.org/wiki/Air_pollution_in_Hong_Kong)

three slides were uploaded to an interactive TV screen in front of them. They received a remote control (Logitech Wireless Presenter R400) in order to click through the slides during their presentation rehearsal. In between two rounds of rehearsal, participants were asked to take a 10-min break for recreation.

The control group's rehearsals were digitized with a high-fidelity Olympus LS-100 audio recorder at 48 kHz/16-bit in a sound-attenuated lecture room at SDU, i.e., the SDU-MCI Innovation Lab. The recordings were made such that it was not possible for smaller head movements of the participants to have a substantial effect on the microphone-to-mouth distance and hence on the signal's intensity level.

The test group's recordings were conducted based on the same procedure (four rounds of rehearsal separated by 10-min breaks), recording device, and recording settings (48 kHz/16-bit and mouth-to-microphone distance). Also the sound-attenuated recording environment was the same as for the control group. However, the test group participants were asked to do their rehearsals in a VR environment. Thus, they were able to address visible (yet virtual) listeners. Like control group participants, test group participants were asked to present persuasively in front of these virtual listeners as if they would really seek their support for the pitched idea. All test group participants had previously gained some experience with VR applications during lectures or events at SDU. So, we can assume that the obtained data is free from any technology-familiarization artifacts.

We used the VR software called "Presentation Simulator"[5] for the experiment. It was installed on a Windows 10 desktop PC. The VR interface was a HTC Vive system. The virtual simulation projected the participants within a virtual room with a virtual audience. Figure 1 shows that the Presentation-Simulator software also allowed the elevator-pitch slide deck to be directly uploaded into the virtual environment and projected by a virtual beamer onto a virtual screen. Thus, the participants were able to see and click through their slides like in the real-world rehearsal condition of the control group. Furthermore, the virtual audience produced a variety of sounds like breathing and coughing in order to enhance the speaker's immersion experience (Pertaub et al. 2002).

4.3 Acoustic Analysis

The recorded sound files were automatically acoustically analyzed (and manually checked and corrected for outliers) using two scripts written for the PRAAT speech-signal processing software.[6] All eight parameters selected in Sect. 3 were measured with these scripts.

[5]Presentation Simulator App, retrieved November 11, 2017 from http://www.presentationsimulator.com/fear-public-speaking/

[6]P. Boersma and D. Weenink, "Praat: doing phonetics by computer [Computer program]. Version 6.0.36," retrieved November 11, 2017 from http://www.praat.org/

The first script applied to the audio files was the "Pause Detector 2" (see De Jong and Wempe 2009 for a description and validation of the script). The script separates the recorded speech signal into speech parts and silent parts. Speech parts are coherent stretches of speech that are framed by pauses or combinations of disfluency and pause. These speech parts are also called Inter-Pausal Units or IPUs. We will use this term henceforth.

The Pause-Detector script determined how much speech was produced by a speaker by counting the total number of syllables in each IPU based on the well-defined local intensity peak that each syllable generates when the speaker's mouth is most open (typically in the middle of the vowel; see the output display of PRAAT in Fig. 3). The total number of overlong pauses or other disfluencies like hesitation particles (eh, ehm, etc.) was counted on an auditory basis, guided by the segmentation and IPU classification of the Pause-Detector script. Overlong pauses are defined as silent intervals longer than 400 ms, as Lövgren and van Doorn (2005) found that such intervals make utterance sequences sound disfluent in more than 90% of the cases. In the following, we will refer to this phenomenologically diverse parameter simply as "disfluencies."

The IPUs were further analyzed by means of Prosody Pro (Xu 2013). The Prosody Pro script measured F0 level, F0 range, intensity level, HNR, and the Hammarberg index. Prosody Pro also determined the duration of the IPU, which, in combination with the number of syllables estimated by the Pause-Detector script, was used to calculate the speaking rate in syllables per second.

For each parameter, Prosody Pro returned one mean value per IPU. Each speaker's elevator-pitch presentation included between 41 and 55 IPUs. That is, the control group and test group samples consisted in total of about 250–300 IPUs. This number simultaneously corresponds to the number of measurements per acoustic parameter and hence to the sizes of the control group and test group samples.

4.4 Statistical Analysis

We used a mixed-design GLM (General Linear Model) for our statistical analysis. Fixed factors were VR and REHEARSAL. The factor VR consisted of two levels, i.e., the control group and test group conditions; REHEARSAL had four levels that represent the four rounds of rehearsal. Note that VR was a between-subject and REHEARSAL a within-subject factor. The GLM included tests for homogeneity of variance among the levels of a factor (Levene's test for the between-subject factor VR, and Mauchly's test for the within-subject factor REHEARSAL). Corrected statistics were used, if the homogeneity of variance was violated by two compared of parameters and conditions (Welch for the between-subject factor VR, and Greenhouse–Geisser for the within-subject factor REHEARSAL).

Dependent variables were the individual acoustic parameters. Subject (SPEAKER) was included as a covariate in order to be able to determine and, if necessary, statistically factor out any individual differences in how speakers handled the

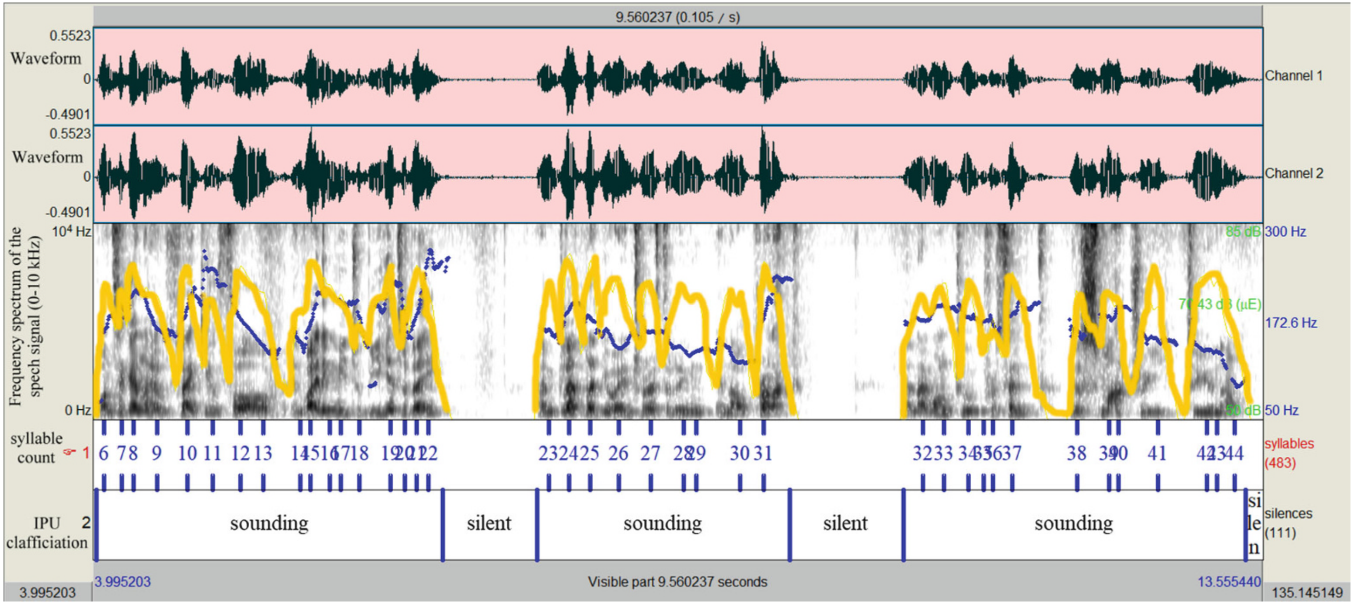

Fig. 3 Example of the acoustically analyzed stereo speech signal of speaker PGH [waveform, spectrogram, F0 contour (blue), intensity contour (yellow)] displayed in PRAAT together with the two time-aligned levels of annotation, i.e., syllable count and the separation into speech parts ("sounding" IPUs) and silent parts (bottom). Source: authors' own screenshot of a "praat" analysis-and-annotation window combination

Table 2 The 2 × 4 conditions of Experiment 1 and their corresponding sample sizes (identical to the total number of IPUs produced by the control group or test group speakers)

Rehearsal	Control group	Test group	
1	260	264	524
2	305	271	576
3	249	282	531
4	285	305	590
	1099	1122	2221

Source: authors' own table

pitch-rehearsal task. The sample sizes of the two fixed factors and their factor levels are specified in Table 2. Finally, note that although eight parameters were determined in the acoustic analysis, only five of them are taken into account for Experiment 1, as Assumptions 1 and 2 do not include any expectations about the intensity level and the two voice quality-related measures HNR and Hammarberg index.

4.5 Results

A descriptive results summary is provided in Fig. 4. Each panel of Fig. 4 addresses one of the five acoustic parameters that are relevant for the assumptions underlying Experiment 1. Vertical differences, i.e., differences in the parametric *distances* between the two curves in a panel, relate to Assumption 1: the adoption of a dialogue speaking style through VR stimulation. Horizontal differences across the four repetitions, i.e., differences between the *courses* of the two curves in a panel, relate to Assumption 2: the speech-erosion effect and the degree of its suppression in a VR setting.

Regarding differences between the *distances* of the two curves in a panel, the GLM revealed several significant main effects of the fixed factor VR. These main effects show that test group participants produced more speech (i.e., a higher total number of syllables) than control group participants [$F(1,2213) = 5238.8$, $p < 0.001$, $\eta_p^2 = 0.70$]. The control group's speech, in turn, was more often interspersed with disfluencies [$F(1,2213) = 1929.1$, $p < 0.001$, $\eta_p^2 = 0.47$]. Furthermore, compared to control group speakers test group speakers gave their elevator pitches on a higher F0 level [$F(1,2213) = 1289.6$, $p < 0.001$, $\eta_p^2 = 0.37$], with a larger F0 range [$F(1,2213) = 799.3$, $p < 0.001$, $\eta_p^2 = 0.27$], and at a slower speaking rate [$F(1,21) = 66.9$, $p < 0.001$, $\eta_p^2 = 0.03$].

Regarding differences between the *courses* of the two curves in a panel, main effects of REHEARSAL were restricted to two consistent changes across both VR conditions: The total number of syllables decreased (i.e., the elevator pitches got shorter) across the four rehearsals [$F(3,2213) = 911.9$, $p < 0.001$, $\eta_p^2 = 0.55$], whereas the speaking rate increased successively [$F(3,2213) = 189.4$, $p < 0.01$, $\eta_p^2 = 0.20$] across the four rehearsals. In addition to these main effects, notable, significant VR∗REHEARSAL interactions were found. Three types of interactions can be distinguished.

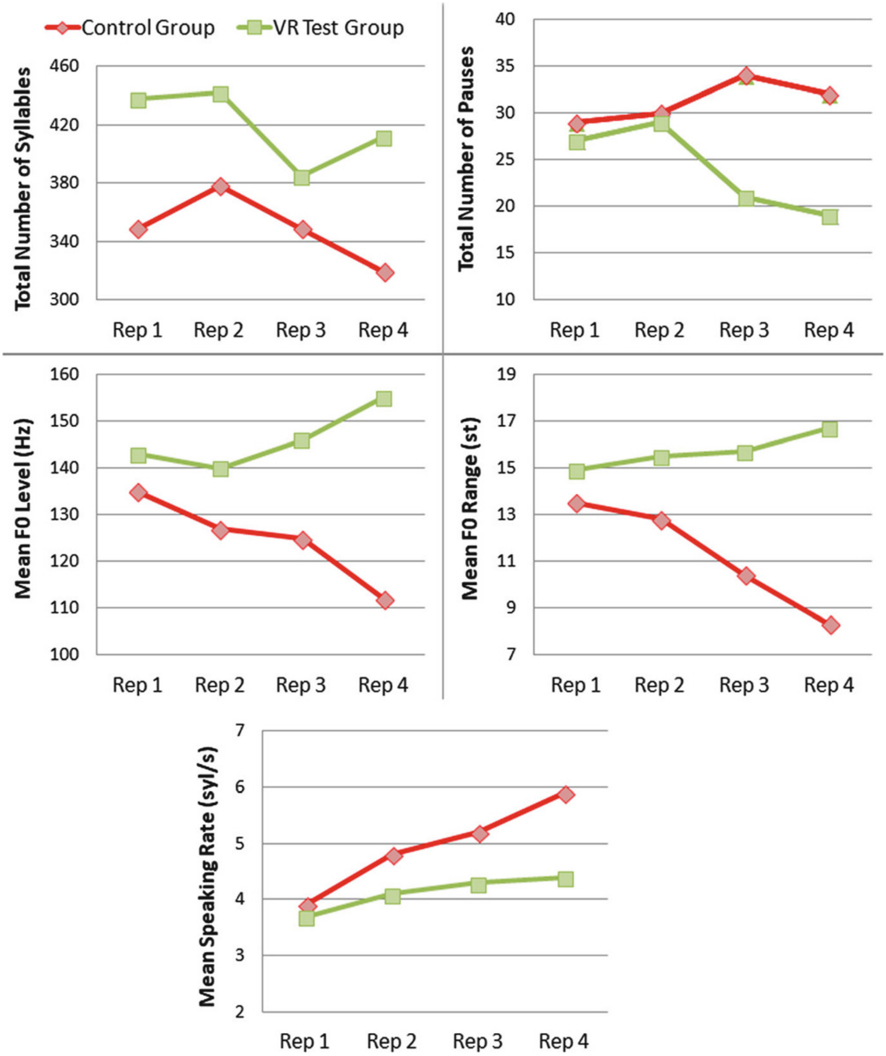

Fig. 4 Results summary of Experiment 1. Each data point represents between 250 and 300 measurements of six male speakers. Source: authors' own figures

The first type of interaction concerns the magnitude of change. For the total number of syllables and the speaking rate, the effect of repeated presentation rehearsal was the same for control group and test group. However, the magnitude of the effect differed and was greater for the control than for the test group. The corresponding VR∗REHEARSAL interactions were significant [$F(3{,}2213) = 147.2$, $p < 0.001$, $\eta_p^2 = 0.17$; $F(3{,}2213) = 427.6$, $p < 0.001$, $\eta_p^2 = 0.37$].

The second type of interaction concerns the affected speaker group. The F0 range changed significantly across the four rounds of rehearsal, but only for control group speakers and not for test group speakers [VR∗REHEARSAL: $F(3{,}2213) = 267.9$, $p < 0.001$, $\eta_p^2 = 0.27$].

The third type of interaction concerns the direction of change. The total number disfluencies and the F0 level both changed significantly across the four rounds of rehearsal, but in opposite directions for control group and test group speakers [$F(3{,}2213) = 629.5, p < 0.001, \eta_p{}^2 = 0.46$; $F(3{,}2213) = 307.8, p < 0.001, \eta_p{}^2 = 0.29$].

Finally, the covariate SPEAKER had a significant main effect on none of the dependent variables nor did it interact with the two factors VR and REHEARSAL. We interpret this as showing that we indeed succeeded with forming two homogeneous speaker groups for our VR and control conditions (by controlling speaker age, educational background, as well as public-speaking and VR experience).

4.6 Interim Discussion

We found evidence that the speakers of the test group gave their elevator pitches in a more listener-oriented tone of voice than the speakers of the control group. Compared to the latter group, the presentations of the VR test group were characterized by a higher F0 level, a larger F0 range, and a slower speaking rate. Presenting in a VR environment also animated the speakers to talk longer. These are all characteristics of a dialogue speaking style rather than a monologue speaking style.

Furthermore, the control group's speech melody became lower and flatter (i.e., more monotonous) across the four rounds of rehearsal. In addition, the members of the control group spoke successively faster and less fluent. In contrast, the test group speakers showed these changes, if at all, only to a lesser degree, or even changed their way of speaking in the opposite direction. For example, the number of disfluencies decreased rather than increased.

For the control group, the overall results pattern is consistent with a speech-erosion effect that emerges and successively increases across the elevator-pitch rehearsals. For the test group, the results pattern shows that the speakers' erosion effect is less strongly pronounced or, for some parameters, even completely absent.

In summary, Experiment 1 provided evidence in clear support of Assumptions 1 and 2 and the corresponding expected speaking behavior. The VR environment prevented to a significant degree that the repeated elevator-pitch training could turn into a mere myo-mechanical exercise. Moreover, the virtual audience caused a response in speaking style comparable to that of a physically present audience. Such an involuntary behavior is in agreement with results of other previous VR studies. For example, such previous VR studies showed that talking in front of a virtually simulated audience was able to first trigger and then reduce the speakers' anxiety of public speaking. This was true, although all participants were fully aware of the virtual nature of the audience (North et al. 1998). Furthermore, talking in front of a positive, neutral, or aggressive virtual audience significantly affected the speakers' anxiety level and its reduction in a positive or negative way (Pertaub et al. 2002).

The conclusions that can be drawn from results of Experiment 1 on speaker charisma are clear. The acoustic-parameter settings of the test group speakers agree much better with a charismatic tone of voice than those of the control group speakers. The latter fact suggests that it is also easier for test group speakers to give a charismatic elevator pitch after they take off the VR glasses and return to a real-world presentation condition. They have already used a more charismatic tone of voice during rehearsal and only have to maintain this tone of voice. In other words, the VR training environment already set the test group into a "presentation mode," whereas the control group underwent a strong speech-erosion effect that set them into an exercise-like "memorization mode," from which they would have to switch back into a "presentation mode" in order to be able to compete with the test group in terms of speaker charisma.

This is the point at which Experiment 2 continues. With reference to Assumption 3, it tests by means of a variation in the virtual speaker-listener distance whether the VR audience simulation is able to stimulate further basic characteristics of a more charismatic tone of voice that are related to an increase in vocal effort. This concerns a louder, higher, and stronger, i.e., less airy, voice. In addition, Experiment 2 will provide initial insights into whether test group speakers, whose pitching in front of a virtual audience stimulates them to adopt a more charismatic tone of voice, also maintain this more charismatic tone of voice if they leave the virtual reality scenario again and return to a real-life pitch-rehearsal setting.

5 Experiment 2

5.1 Method

Experiment 2 is essentially a repetition of Experiment 1, except that the test group's quadripartite elevator-pitch rehearsal sequence was changed from [iii]–[iii]–[iii]–[iii] to [i]–[ii]–[iii]–[i], with the order of conditions [ii] and [iii] being inverted for half of the speaker sample. That is, in order to rule out (or rather balance out) any order effects on the presentation performance in the virtual meeting-room and keynote-hall conditions [ii] and [iii], half of the test group received the two VR conditions in the order [ii]–[iii]. The other half received them in the order [iii]–[ii]. The control group practiced the elevator pitch again four times in a row in baseline condition [i] only, just as in Experiment 1.

Also like in Experiment 1, control group and test group consisted of six male speakers each. They were recruited from the same pool of SDU-internal participants as in Experiment 1 (associated with the Innovation-and-Business study program). The $2 \times 6 = 12$ speakers of Experiment 2 also had some initial experience with acting in VR environments, and they were all equally familiar with the elevator-pitch concept. The mean age of the speaker sample was 26.6 years, and all speakers were again highly proficient L2 speakers of English.

Experiment 2 was conducted in exactly the same way as Experiment 1, from the instruction of the speakers and the slide deck that was handed out to them through the room and its recording equipment to the analysis and script-based measurement

Table 3 The 2 × 4 conditions of Experiment 2 and their corresponding sample sizes (identical to the total number of IPUs produced by the control group or test group speakers)

Rehearsal	Control group	Test group	
1	291	262	553
2	296	262	558
3	300	310	610
4	223	299	522
	1100	1133	2233

Source: authors' own table

of the acoustic parameters. There were only two minor differences. First, unlike Experiment 1, Experiment 2 took into account all eight parameters listed in Table 1. Second, the statistical analysis of the data was based on two mixed-design GLMs as control and test group were analyzed separately. Thus, REHEARSAL was the only fixed factor in both GLMs. So, we used repeated-measures GLMs. Like in Experiment 1, subject (SPEAKER) was included as a covariate, and violations of homogeneity of variances were addressed using the Greenhouse–Geisser correction. Table 3 specifies the sample sizes of all four factor levels (i.e., the number of IPUs and measurements) of the two GLMs.

5.2 Results

As can be seen in Fig. 5, the results of the control group show clear changes across the four elevator-pitch rehearsals. The factor REHEARSAL had a significant main effect on all measured parameters [$95.1 \leq F(3,1106) \leq 879.7$, $p < 0.001$, $0.21 \leq \eta_p^2 \leq 0.71$]. According to multiple-comparisons tests (with Sidak correction), the amount of speech and hence the duration of the elevator pitch (represented by the total number of syllables) decreased significantly across the first three rounds of repetition ($p < 0.01$). F0 level and range decreased as well, especially from repetition 1 to 2 ($p < 0.01$) and from 3 to 4 ($p < 0.001$). The speaking rate increased significantly after each repetition ($p < 0.01$). In addition, we found the intensity level and the HNR level to decrease and the Hammarberg index to increase after the second time ($p < 0.01$) the speakers rehearsed the elevator pitch.

When looking at the results of the VR test group, remember that these speakers went through all three experimental conditions in the order [i]–[ii]–[iii]–[i] or [i]–[iii]–[ii]–[i]. That is, the first and the last rehearsals took place under the same circumstances as in the control group condition [i]. Speakers of both groups practiced the pitch alone in a silent room and only in front of an imagined audience. Given that, it is plausible and adds to the validity and reliability of our data that the results for control group and test group are virtually identical for the first condition [i] rehearsal of the elevator pitch; see Fig. 5.

However, after the first rehearsal, the test group started deviating considerably from the control group. The main effect of REHEARSAL was in all cases significant [$57.4 \leq F(3,1129) \leq 1479.0$, $p < 0.001$, $0.13 \leq \eta_p^2 \leq 0.80$] like for the control

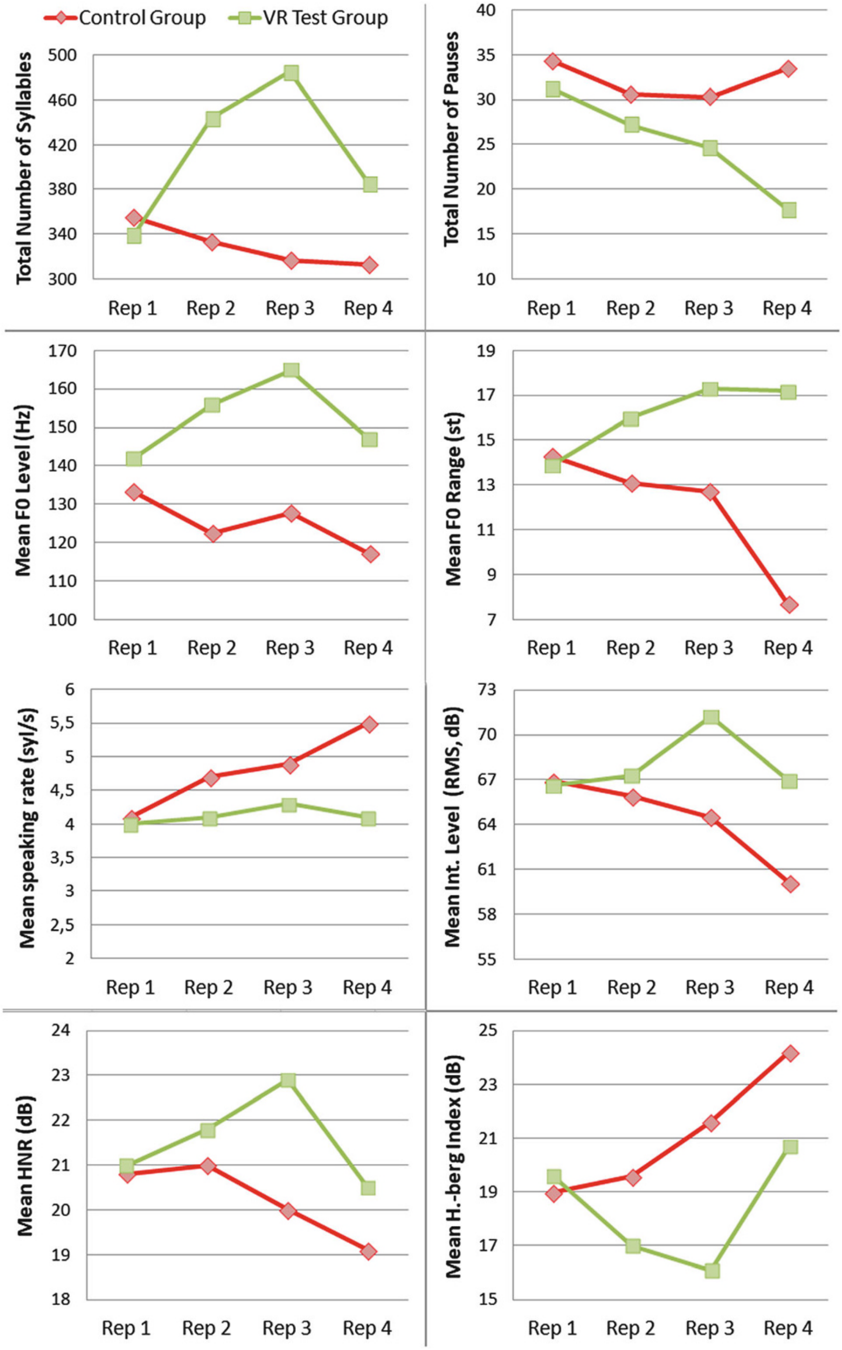

Fig. 5 Results summary of Experiment 2. Each data point represents between 250 and 300 measurements of six male speakers. Note that, for the VR test group (green lines), repetitions 1–4 correspond to conditions [i], [ii], [iii], and [i]. Source: authors' own figures

group speakers. But unlike for the control group speakers, multiple-comparisons tests (with Sidak correction) show that test group speakers produced significantly more speech, i.e., they gave longer elevator pitches, when they moved on from the baseline condition [i] to the VR conditions. In the case of VR condition [ii], this increase in the total number of syllables was almost 30% ($p < 0.001$). Further significant parameter increases occurred in condition [ii] for the F0 level and range ($p < 0.01$) and the mean HNR level ($p < 0.01$). The total number of disfluencies decreased significantly (at $p < 0.01$) from condition [i] to condition [ii], and so did the Hammarberg index ($p < 0.001$).

All these changes that characterized VR condition [ii] relative to the first baseline condition [i] were still larger in VR condition [iii], with $p < 0.05$ to $p < 0.001$ for each parameter. In addition, VR condition [iii] also caused the speakers' intensity level to increase significantly ($p < 0.01$). The only exception to the VR-induced acoustic-parameter changes relative to the first baseline condition [i] was the speaking rate. It did not change at all from the first baseline condition [i] to the VR condition [ii] and just showed a marginally significant increase from VR condition [ii] to VR condition [iii] ($p = 0.05$).

When the test group speakers returned from the two VR-supported rounds of rehearsal to the fourth and last elevator-pitch rehearsal in baseline condition [i], almost all tone-of-voice parameters rebounded toward their initial condition [i] parameter levels ($p < 0.01$ to $p < 0.001$, in comparison to both VR conditions). The only two exceptions are the F0 range and the total number of disfluencies. The F0 range showed no change at all and hence also no significant decrease from the VR conditions to the final baseline condition [i]. The total number of disfluencies did not rise again, but rather continued to decrease significantly from the VR conditions to the final baseline condition [i] ($p < 0.01$). For those parameters that moved back in the direction of their initial condition [i] level, it is important to note that the total number of syllables as well as the F0 level stay at a level significantly above their initial condition [i] level ($p < 0.05$). The speaking rate showed no significant increase from the first to the last condition [i] rehearsal, unlike for the control group speakers.

Finally, like in Experiment 1, the covariate SPEAKER had no significant main effect on the data.

5.3 Discussion of the Production Data

Experiment 2 replicated the key findings of Experiment 1. For the control group, we found the speech-erosion effect again. It manifested itself in an acceleration of the speaking rate, in a lowering and narrowing of the F0 level and range as well as in a strong increase in disfluencies. Experiment 2 adds to this picture that repeatedly rehearsing one's elevator pitch alone in a silent room has further unfavorable effects in the form of a decreasing intensity level, i.e., a quieter speech, and lower or higher levels of HNR and the Hammarberg index, respectively. These changes make a voice sound airier and thinner.

For the test group, Experiment 2 replicated the beneficial effect of VR-based elevator-pitch training on the speakers' tone of voice. The test group's speech becomes more audience-oriented and dialogue-like, which causes the F0 level and range to increase and makes the speakers talk longer.

Furthermore, the data of Experiment 2 suggest that the speech-erosion effect was completely suppressed for the test group, whereas the test group in Experiment 1 still showed minor traces of the speech-erosion effect in terms of a slight increase in speaking rate and a small decrease in syllable number. A possible explanation for this difference could be that the test group in Experiment 2 practiced the elevator pitch under variable rehearsal conditions that included the two VR conditions [ii] and [iii] and the baseline condition [i], whereas the VR test group of Experiment 1 made their rehearsals in VR condition [iii] only. The resulting implication of this explanation is that elevator-pitch rehearsals are generally more effective and less susceptible to the speech-erosion effect if speakers vary the circumstances under which they practice their presentation. This is especially true of VR-based training, which proved to be generally superior to traditional training (alone in a quiet room) and for which variations of the presentation conditions are even easier to implement. These implications clearly represent a worthwhile starting point for a series of future experiments.

Besides replicating the findings of Experiment 1, Experiment 2 tested Assumption 3 that the VR environment not only causes speakers to address the virtual audience like a real audience, but also makes them adjust the vocal effort of their speech to the acoustic conditions of the virtual room. Specifically, we expected based on Assumption 3 that the virtual keynote-hall condition [iii] with its larger speaker-listener distance would elicit a higher level of vocal effort from the speakers than the meeting-room condition [ii] with its smaller speaker-listener distance. This expectation is met by our data. We found the elevator pitches in the keynote-hall condition [iii] to increase the speakers' F0, intensity, and HNR levels and lower their Hammarberg index compared to the either preceding or following meeting-room condition [ii]. All these changes are consistent with an increase in vocal effort. Beyond this adaptation to the virtual speaker-listener distance, condition [iii] also further extended the speakers' F0 ranges, made them talk longer than in condition [ii], and further reduced the number of disfluency phenomena.

Finally, the results of Experiment 2 provided further indirect support that the use of digital VR technology for innovative elevator-pitch training has made the test group performances more charismatic—with respect to all acoustic tone-of-voice parameters that we analyzed, firstly, by counteracting the speech-erosion effect and, secondly, spontaneously triggering a dialogue-like speaking style and a higher level of vocal effort. In particular, our results suggest that (a) the repeated presentation rehearsals made the control group speakers sound less charismatic in their fourth round compared to their first round, (b) the test group speakers of Experiment 2 sound more charismatic in keynote-hall condition [iii] than in meeting-room condition [ii], and (c) this group of speakers still sounds more charismatic in their fourth than in their first round of rehearsal, i.e., after they took off of their VR glasses and returned to the self-directed baseline pitch training of condition [i].

In order to substantiate these signal-based conclusions (a)–(c) by direct empirical evidence, Experiment 3 was conducted to make listeners compare and assess excerpts from the recorded elevator-pitch rehearsals with respect to perceived speaker charisma.

6 Experiment 3

6.1 Participants

A total of 31 listeners took part in the experiment. All listeners were male (like the speakers who they heard and rated) in order to rule out that a sex-specific rating behavior could bias our results (cf. Brooks et al. 2014; Balachandra et al. 2013; Berger et al. 2017). Previous studies found (and our own ongoing experiments corroborate and refine these findings) that, all else equal, female speakers sound less charismatic in the ears of male than in the ears of female listeners. Female listeners, in turn, react more sensitively to charisma signals in male than in female speech. That is, male and female listeners do not fundamentally disagree about which acoustic tone-of-voice parameters make a speaker sound charismatic. They only differ in how highly they rank each parameter and in what they consider an appropriate parameter level (and in the degree to with which they include other factors like visual attractiveness, clothing, foreign accent, etc., in the perception of speaker charisma; Brem and Niebuhr 2019). Thus, excluding female listeners was to reduce the level of between-subject variability in our rating data. Qualitatively, the results gained from male listeners will also generalize to female listeners, but with some predictable quantitative differences. These differences are, however, irrelevant for the conclusions of this study.

The listeners were recruited from the pool of friends and acquaintances of the authors and were predominantly German native speakers aged between 21 and 46 years. Their background was in linguistics rather than economics or entrepreneurship. All listeners stated that they had normal hearing abilities and were fluent in English, i.e., the language of the elevator pitches.

6.2 Stimuli

The stimulus pairs of Experiment 3 were based on excerpts from the pitches recorded in Experiment 2. The two stimuli of a pair were always excerpts of the same speaker, but from different conditions of the experiment. Figure 6 illustrates the four paired comparisons that were included in the experiment. One paired comparison was

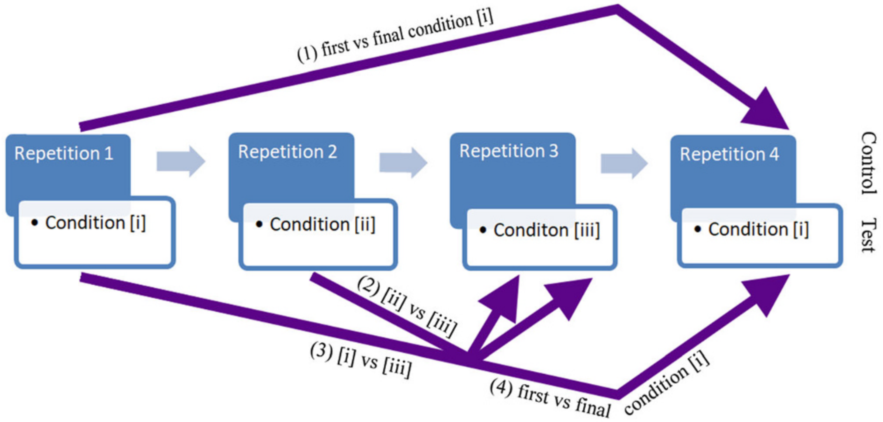

Fig. 6 Illustration of conditions compared in the stimulus pairs of Experiment 3. Source: authors' own figure

based on the control group speakers' pitches; the other three come from the test group speakers' pitches.

In the case of the control group speakers, the paired comparison concerned the first rehearsal and the fourth and final rehearsal of the elevator pitch, each made under baseline condition [i], in which speakers presented the pitch in a self-directed way while being alone in a silent room.

In the case of the test group speakers, one paired comparison also concerned the first and the final rehearsal of the elevator pitch under condition [i]. In addition, the first condition [i] rehearsal was compared to the virtual keynote-hall condition [iii] rehearsal. The latter condition [iii], in turn, was compared to the virtual meeting-room condition [ii].

Since all four comparisons included pitch excerpts of all six speakers of a group, Experiment 3 consisted of a total of $6 \times 4 = 24$ stimulus pairs or 48 individual stimuli. Before pairing them up, the 48 individual stimuli were normalized to an identical loudness level that corresponded to 90% of the maximum dynamic range of the signal.

The stimuli of a pair were about 5 s long. Only sequences of complete IPUs were extracted from the elevator pitches, which required deviations from the 5-s criterion by up to 500 ms. These deviations are still below the just noticeable difference for duration changes in speech (e.g., Klatt and Cooper 1975), which is important to note because studies like those of Rosenberg and Hirschberg (2009) found a positive correlation between stimulus duration and perceived speaker charisma. In addition, the two excerpts of a stimulus pair were as far as possible identical in wording, particularly in those respects that Rosenberg and Hirschberg (2009) and Antonakis et al. (2011) found to affect speaker charisma.

The stimuli of a pair were separated by a silent break of 1 s. Silent breaks between stimuli pairs were 2 s long.

Note that due to the within-speaker comparison design, any differences between speakers, for example, due to individual voice characteristics of foreign-accent levels, are irrelevant. Experiment 3 does not test and compare the absolute performances of the individual speakers, but whether there are consistent relative changes across the speakers that are systematically related to the pitching conditions of Experiment 2 and associated with perceived charisma.

6.3 Procedure

In the perception experiment, the 24 stimulus pairs were repeated six times and presented to the listeners in an overall randomized order. So there were 144 stimuli to rate. This number is an order of magnitude that proved to be manageable for listeners in a single session without significant fatigue or stress effects (Kohler 1991; Clayards et al. 2008; D'Imperio et al. 2010; Barnes et al. 2012). The order of the stimuli in the pairs was balanced, i.e., over the six repetitions the pairs were rated three times in the order AB and three times in the order BA.

The participants took part in the experiment individually via a laptop that was equipped with a hi-fi sound card. On the laptop, the experiment was created and set up on the basis of a PRAAT MFC script (Beck 2015). All participants heard the stimuli via the same pair of headphones (Sennheiser HD 457) at a preset, constant volume.

The task of the participants was to rate in which of the two stimuli of a pair the speaker sounds more charismatic. To that end, the participants used a 7-point Likert scale, consisting of a neutral center ("undecided") and three levels each for the first and the second stimulus of a pair. The three levels were paraphrased as "The speaker sounds..." (1) "somewhat more charismatic in stimulus __," (2) "more charismatic in stimulus __," (3) "much more charismatic in stimulus __."

In order to give the listeners a more specific idea of the concept of charisma, the term "charismatic" was contextualized with the four personality traits "convincing," "inspiring," "visionary," and "enthusiastic." These terms were also clearly visible on the laptop screen above the Likert scale of each stimulus pair. The four traits were chosen because they were found to be highly correlated with the concept of charisma in previous studies (Rosenberg and Hirschberg 2009; Weninger et al. 2012). The listeners were asked to treat speaker charisma in their ratings as a bundle of the four personality traits. In addition, they were told that charisma and the associated four traits equip a speaker with leadership and "maker" qualities as well as with persuasive power. On this basis, the listeners were asked to put themselves in the role of a potential investor and evaluate the stimuli as sections of a speaker's investor pitch, performed with the aim to convince them of the speaker's idea and an investment in this idea.

The participants made their charisma ratings by tapping the respective scale point on the laptop screen with their finger (the display was a touch screen). The whole experiment, including instruction and debriefing, took about 25 min.

6.4 Statistical Analysis

For the statistical analysis of the ratings, we treated the 7-point Likert scale as ranging from −3 ("the speaker sounds much more charismatic in stimulus A of the pair") to +3 ("the speaker sounds much more charismatic in stimulus B of the pair"). Based on these positive and negative scale values, we added up the ratings per participant for all stimulus pairs of a comparison condition, i.e., for the four conditions in Fig. 6, taking into account the AB and BA stimulus orders. In total, each sum contained 36 individual values per participant (6 speakers × 6 repetitions of the stimulus pair).

The aim of the statistical analysis was to determine if the rating behavior of all listeners would result in a significant deflection from 0 on the rating scale, i.e., in a systematic preference for either the first or second stimulus. Thus, we had to find out whether the positive values exceed—in frequency and/or magnitude—the negative ones or vice versa. Accordingly, for each of the experiment's four comparison conditions, we separated the positive and negative values and compared them as absolute values (moduli) in a *t*-test for unpaired samples (paired samples could not be used due to unequal numbers of absolute values for stimulus A and B in each comparison condition). *F*-tests were conducted prior to the *t*-tests to check the homogeneity of variance of two compared sets of ratings; *df*-adjustments were made if the homogeneity criterion was violated.

6.5 Results

For the comparison of the control group's first and fourth rehearsal under condition [i], the results across all six speakers of Experiment 3 clearly show a significant listener preference of the first rehearsal over the forth one in terms of perceived speaker charisma [$t(21.8) = 3.73$, $p = 0.004$]. The deflection of the ratings from the center of the scale was more than one scale point; see Fig. 7. About 70% of all listeners (i.e., 22 out of 31) perceived the 6 speakers to sound somewhat more, more, or much more charismatic in the first than in the fourth rehearsal.

The test group's comparison of the first and final rehearsal under condition [i] (whereby the final one was preceded by the two VR conditions [ii] and [iii]) resulted in a diametrically opposed rating behavior. Now, it was the final rehearsal in which the speakers sounded somewhat more, more, or much more charismatic to the listeners. The preference was significant [$t(12.17) = -3.49$, $p = 0.002$]. The deflection of the ratings from the center of the scale was only half a scale point, though, and based on a minority of 45% of all listeners, who, however, gave clear ratings in favor of the final rehearsal, whereas the other 55% of the listeners were more undecided and gave ratings closer to the scale center.

The comparison of the meeting-room pitching condition [ii] with the keynote-hall pitching condition [iii] of the VR test group yielded clearer results. In the ears of the

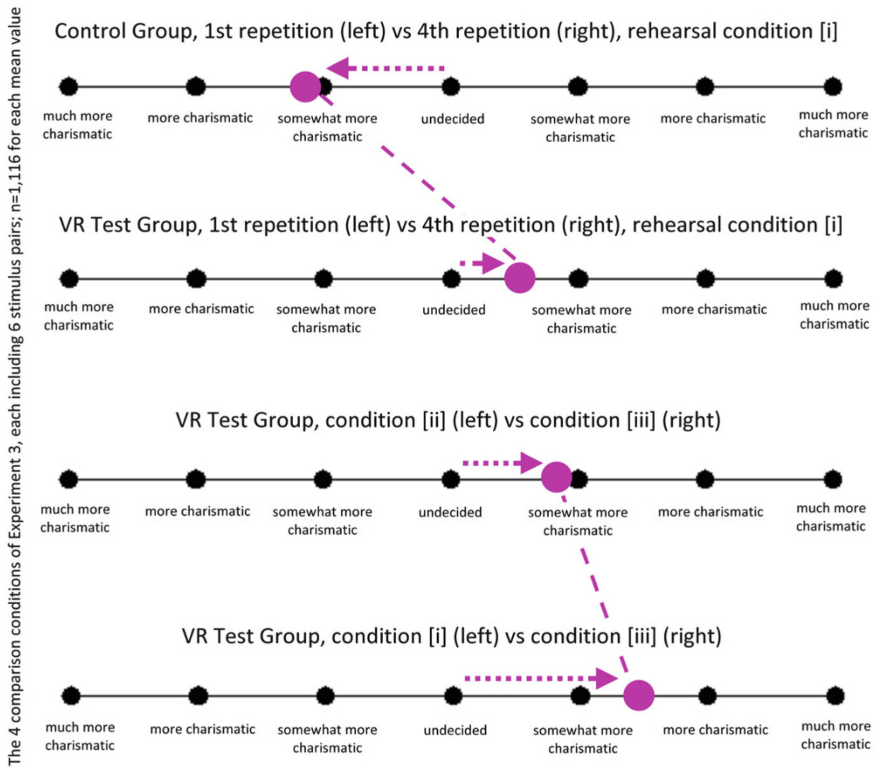

Fig. 7 Average ratings of all 31 participants on the given 7-point Likert scale for each of the four comparison conditions of Experiment 3. Source: authors' own figure

listeners, the speakers sounded more charismatic in the keynote-hall pitching condition [iii] than in the meeting-room pitching condition [ii]. The difference was about one scale point and significant [$t(7.22) = -4.30$, $p < 0.001$]. A clear majority of 75% (23 out of 31) of the listeners preferred the elevator-pitch excerpts of the speakers who presented in the keynote-hall condition [iii]. Only 1 out of the 31 participants consistently rated the speakers in the meeting-room condition to be "more charismatic" than in the keynote-hall condition.

The comparison of condition [i] with the VR-supported keynote-hall condition [iii] was clearly in favor of the VR condition. Like in the comparison of the two VR conditions [ii] and [iii], 75% of all listeners preferred condition [iii]. A total of 42% (13 out of 31 listeners) even found the speakers in condition [iii] to sound "more" or "much more" charismatic than in condition [i]. Accordingly, the deflection of the ratings from the center of the scale was on average almost 1.5 scale points. This deflection was significant [$t(7.22) = -4.89$, $p < 0.001$].

6.6 Discussion of the Perception Data

Experiment 3 was conducted with the aim to substantiate the conclusions drawn in the paper by relating the acoustic tone-of-voice parameter changes elicited in Experiment 2 to perceived speaker charisma. The expectations that underlay our four compared pitching conditions are clearly borne out by the listeners' charisma ratings.

First, the speech-erosion effect that emerged and grew stronger across the four rounds of repetition in the control group speakers' traditional training of their elevator pitch alone in a silent room is indeed unfavorable for perceived speaker charisma (first vs. fourth rehearsal under condition [i]). The charisma signals in the speakers' tone of voice are severely reduced and so is the charismatic impact of the speakers on listeners. Second, a VR-based elevator-pitch rehearsal cannot only suppress this erosion effect, it also stimulates a more charismatic tone of voice during pitch rehearsal (condition [i] vs. [iii], test group). Third, this beneficial effect of VR-based pitch training is not immediately gone as soon as speakers take off their VR glasses and rehearse the same pitch again in real life. Even in the evidentially unfavorable condition [i] rehearsal setting speakers sound more charismatic to listeners if they have previously practiced their pitch in a VR setting (first vs. final rehearsal under condition [i], test group). Fourth, the beneficial effect of VR-based pitch training is further enhanced by an increased vocal effort (condition [ii] vs. [iii], test group).

7 General Discussion, Conclusions, and Implications

It was in June 2013 when German Chancellor Angela Merkel told media representatives at an international press conference that the Internet is still largely "uncharted territory." This sentence went around the world (Dewey 2013; Strange 2013) and sparked a debate in Germany and other countries about the status of digital technologies in business, society, and politics, about how much the economy is shaping digital technologies or vice versa, and whether or not politics can or even must play a (regulating and/or facilitating) role in this business-technology connection. Today, almost exactly 5 years later, no one would want to question that digital technologies have arrived at the hearts of our societies and economies. In the field of economy, digital technologies are primarily discussed with a focus on competitiveness, productivity, and innovation. In this chapter, the focus is a bit different, i.e., on technologies for digitally supported learning.

Individuals who can convince others of themselves and their ideas, goals, and offers become the more important the smaller a company is. Those who agree with this fact also agree that the power of persuasion, i.e., charisma, is a key factor for small businesses. Even more essential is charisma for entrepreneurs who need to go through a series of legitimizing, networking, and fund-raising activities before they can actually build up their own sustainable small business (Cunningham 2010; Colombo and Grilli 2010; Kang et al. 2015; Fisher et al. 2017; Hadley et al. 2018).

Studies have consistently shown that charismatic leadership skills are based primarily on the correct tone of voice of a speaker (Holladay and Coombs 1994; Shea and Howell 1999; Fox Cabane 2012; Chen et al. 2014). Tone of voice refers to a combination of timbre, tempo, and melody that has to fit in with the situational context, the audience, and the speaker himself or herself. But entrepreneurs who want to learn more about this charismatic tone of voice and, to that end, visit charisma coaches or consult traditional rhetorical guidebooks often find themselves faced with vague, descriptive, and sometimes even contradictory statements about how they can become more charismatic speakers and, thus, more successful in attracting funding in, for example, investor-pitch competitions.

Against this background, we started PERCY, i.e., a new acoustically driven interface between digital technologies on the one hand and fundamental entrepreneurial skills on the other (Niebuhr et al. 2017). The PERCY project aims to test and introduce digital learning technologies that help entrepreneurs find the right charismatic tone of voice and master it effectively and with high proficiency. To that end, PERCY strives to precisely quantify and objectively evaluate the charismatic impact of a speaker's tone of voice. Although "there is a superiority of the audible impression over the visible" (Amon 2016: 20, first author's translation) that motivates and justifies PERCY's initial focus on the speaker's tone of voice, the long-term goal is to extend the project's experimental approach to all other ingredients of perceived speaker charisma and, on this basis, to develop a new integrative, objective, and quantitative model of speaker charisma. However, the current focus—including the one of this paper—is still on the tone of voice.

Based on the PERCY framework, this paper tested if, in which way, and to what degree rehearsing an elevator pitch (a special short form of investor pitch) in a VR environment and in front of a VR audience is superior to the traditional rehearsal setting in which the speaker (entrepreneur) practices his or her pitch alone in a silent room with nobody to address except for an imagined audience.

We carried out two production experiments in which we compared the acoustically analyzed speech behavior of a VR test group to that of a traditionally rehearsing control group. Each group practiced the same investor pitch multiple times in a row. The production experiments were flanked by a perception experiment which cross-validated the assumed links between acoustic parameter changes and perceived speaker charisma.

The following was found: First, pitches that are traditionally rehearsed alone in a silent room become subject to a speech-erosion effect. It makes the speech faster (and therefore probably also sloppier), increases the number of disfluencies, and lowers and flattens a speaker's F0 patterns. In consequence, the speech-erosion effect strongly reduces perceived speaker charisma. The effect already sets in after the first round of rehearsal, and the consistency with which it affects the control group speakers suggests that it occurs inevitably, also for speakers who have—like in our study—some experience in entrepreneurship matters and investor-pitch presentations. Second, the use of digital VR technology for investor-pitch training was able to strongly reduce (Experiment 1) or even completely suppress (Experiment 2) the speech-erosion effect in speakers, even after multiple rounds of rehearsal.

Third, the use of digital VR technology had a beneficial influence on the speakers' presentation style. Although the speakers knew that their audience and pitching environment were only virtual, they automatically used a more audience-oriented dialogue-like way of speaking, and, if the room was larger and the audience further away from the speaker, they additionally increased their vocal effort. Both of these factors cause acoustic parameter changes that make a speaker's voice sound more charismatic. These changes include higher F0 and intensity levels, an expanded F0 range, fewer disfluencies, higher HNR values, lower values of the Hammarberg index, and, generally, more speech. Fourth, these automatically stimulated changes partly persist when speakers take off their VR glasses and return to a real-world investor-pitch presentation setting. This is true even if this setting is the traditional rehearsal setting in which the speaker pitches alone in a silent room. Among those parameters that persist, the most critical one, i.e., the one with the biggest positive effect on perceived charisma, is the expanded F0 range (Strangert and Gustafson 2008; Berger et al. 2017).

In conclusion, we have presented cross-validated production and perception evidence for how a specific piece of digital technology, i.e., a simulated slide-deck presentation in front of a VR audience, can be used to reshape traditional structures in entrepreneurship, in our case the structures in which entrepreneurial speakers prepare for an investor pitch presentation. Yet, the exact impact of this new piece of digital technology on real investor-pitch performances and success rates still needs to be demonstrated and quantified, of course. The quantification task in particular requires that, unlike in our study, female speakers and their behavioral response to VR training have to be taken into account as well.

The most important follow-up questions raised by our results are whether those speakers who have undergone the speech-erosion effect during pitch rehearsal do in fact have a harder time to "reset" this effect and switch to a more charismatic tone of voice after rehearsal and whether those speakers whose charismatic tone of voice was automatically enhanced due to VR stimulation really feel, understand, and, thus, learn at an intuitive level how their tone of voice should sound in the actual presentation situation after rehearsal. That is, the questions are whether speakers rehearsing in a traditional self-directed setting have an inherent disadvantage, and, on the other hand, whether the VR-supported rehearsal gives speakers an inherent advantage in that it equips them with a charismatic tone-of-voice setting that is stable and reliably retrievable also in the stressful situation of an investor pitch.

With reference to some pilot data gained in a regular 10-week course on "Persuasive Communication" for Innovation-and-Business students at the University of Southern Denmark, it seems to us that the beneficial effect of VR-based pitch training can indeed become permanent and stress-resistant. That is, speakers consolidate their more charismatic tone of voice and also transfer it to investor-pitch presentations, provided that the VR technology is continuously used for pitch training over several weeks. A further pedagogical advantage in this context is that VR-based pitch training saves speakers from having to hear the same instructions and corrections from the course instructor over and over again (which easily leads to anger and frustration). The VR environment automatically triggers the correct speech behavior, which then only needs to be positively reinforced, refined, and expanded by the course instructor in relation to other aspects of a charismatic performance, such as attire, body language, and choice of words. Integrating these many different sources of perceived speaker charisma is a research field in its own right. It goes beyond mere technological questions, but is indeed also part of the PERCY project (cf. Brem and Niebuhr 2019).

Within a few years, we will have collected enough pitch-training data with and without VR support in the "Persuasive Communication" classes in order to make more solid and accurate statements about whether and under what conditions the benefits of VR-based pitch training turn into stable and reliable patterns of behavior. Until then, based on the present findings, our advice for practitioners is to rehearse their investor pitches in a VR environment, choosing the largest room and the greatest speaker-listener distance that the simulation offers. This primary rehearsal environment should be interspersed with other VR environments (like a small meeting room) in order to introduce some variation in the pitch training and further minimize a potential speech-erosion effect. It seems beneficial to do a least round of VR-supported pitch rehearsal immediately before the presentation is given in real life.

For those speakers who have no access to a VR slide-deck presentation stimulation, our (preliminary) advice is not to rehearse the investor pitch too often in direct succession, but to leave quite some time in between two rounds of rehearsal, definitely more than the 10-min time slot that separated two rounds of rehearsal in this study. This should reduce the speech-erosion effect. Moreover, for the latter reason, it also seems not beneficial to do such a traditional rehearsal immediately before the pitch is given in the actual presentation situation.

Turning from a practical to a research point of view, our paper has identified the VR presentation simulation as a new test bed for investigating various practical and theoretical aspects in and around the entrepreneurial investor pitch, its content and structure, and its psychological momentum that is constituted by the speaker-audience relationship. For example, recordings during a VR presentation simulation cannot only be made for a speaker's voice but also for a speaker's head movements and arm/hand gestures, based on the headset and the two handheld controllers that she or he uses during the immersion. Combining these signals offers a huge potential for studying, understanding, and eventually training how the interplay of acoustic tone-of-voice parameters and body language relates to perceived speaker charisma. Moreover, while we argued in this chapter that the focus on male speakers is not a critical limitation and that the data will—with some quantitative differences—also apply to female speakers, the interplay of body language and tone of voice will certainly include some sex-specific differences on the part of both speakers and listeners. For instance, studies show that, compared to males, females show a stronger avoidance behavior in social interaction (Caballo et al. 2014), which manifests itself, among other things, in a lack of eye contact and backward head movements (Wieser et al. 2010). Research needs to determine whether this behavior and its associated body language patterns are unfavorable for charisma perception. Regarding investor-pitch training or, more generally, public-speaking training, findings like those of Wieser et al. (2010) and Caballo et al. (2014) might mean that females have to start at a more basic training level than males and/or that their initial training needs to be more strongly focused on body language than on the tone of voice.

Additionally, it would be desirable to further develop the VR presentation stimulation in terms of interactive virtual audiences. Inspired by human–machine interaction systems like Cicero (Batrinca et al. 2013) and MACH (My Automated Conversation coacH, Hoque et al. 2013) that were successfully tested for public-speaking and job-interview training, we currently plan to develop our own VR interface that evaluates a speaker's presentation performance based on acoustic parameter analyses and then adjusts the visible behavior of the VR audience accordingly on a attentive-distracted scale. Further features of such an interactive simulation could be that speakers can practice their investor pitches in front of either a friendly or a very critical virtual audience or that the speaker's integrated acoustic charisma score (see Niebuhr et al. 2017) is projected directly into the simulation environment.

There are many possibilities, including new digital technologies that can visualize acoustic charisma parameters for a more tangible learning experience, or speech-synthesis applications that can provide speakers with more easily implementable feedback in that they play back single statements in the speakers' own voices but with a more charismatic tone of voice. Whatever the future solutions and applications will be, we are sure that they will lead to a situation in which digital technologies will no longer play a primary role in the entrepreneurs' businesses alone, but also in the entrepreneurs' education and training.

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Effects of Internal Corporate Venturing on the Transformation of Established Companies

Tackling the Digitalization Challenge

Christoph J. Selig, Tim Gasser, and Guido H. Baltes

Abstract The organizational capability to adapt to the fast and radical changes of market parameters becomes a prerequisite for companies' long-term survival. In this context, organizational ambidexterity has gained much attention in research and practice. It is the capability to develop new businesses (exploration) while simultaneously optimizing the existing core businesses (exploitation). Established companies face several challenges in achieving this capability, as the underlying learning modes of exploration and exploitation are mutually incompatible. One way to solve these challenges is to separate the exploration-oriented part from the core organization. Corporate venturing has been widely recognized as one tool to create these dual structures to develop new businesses, based on discontinuous innovation. In recent times, new corporate venturing forms emerge in practice. This growing number of different forms has led to new applications of corporate venturing which go beyond the pure development of new businesses, toward supporting the entrepreneurial transformation of companies. This study aims at answering how different corporate venturing forms contribute to the strategic renewal of established companies. For this purpose, qualitative research methods are used to analyze data from 17 interviews conducted in two German high-tech companies. The study at hand provides empirical evidence in the field of corporate venturing by uncovering new insights about the different transformational effects of corporate venturing initiatives on the core organization. It further reveals that corporate venturing forms can be classified into two categories according to their respective level of entrepreneurship and frequency of execution. Both categories exhibit different transformational effects and can be understood as being complementary to each other.

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1 Corporate Venturing as a Strategic Tool to Transform Established Companies

In today's volatile market environments, innovation is a key driver for change. This is especially the case for so-called *discontinuous innovation* (Veryzer 1998; Markides 2006) which has the potential to transform industries as a whole, by changing existing market parameters fundamentally (Christensen and Overdorf 2000). Trends like digitalization and globalization seem to foster this type of innovation additionally (Lyytinen et al. 2016). To stay competitive in volatile environments, companies need to become more entrepreneurial and agile (Weiblen and Chesbrough 2015), which supports them in developing discontinuous innovation while simultaneously improving their existing business with incremental and processual innovation (O'Reilly and Tushman 2013).

However, especially established companies struggle with pursuing discontinuous innovation, which seems to be rooted in their organizational structures. They are highly optimized to improve existing products and processes (Govindarajan and Trimble 2010, p. 10), but are rather toxic for the creation of discontinuous innovation (Sandberg and Aarikka-Stenroos 2014). Start-ups on the other hand seem to be more suitable for the creation of more discontinuous types of innovation (Freeman and Engel 2007). Consequently, established companies aim at adopting or integrating start-up-like structures to overcome or compensate their path-dependent handicaps. The creation of start-up-like structures is frequently discussed using the notion of *corporate venturing* (CV), which describes "the birth of new businesses within existing organizations" (Guth and Ginsberg 1990, p. 5). Various studies have linked CV to positive financial and strategic outcomes, e.g., increasing performance and growth of companies (Battistini et al. 2013; Burgelman 1983; Zahra and Covin 1995) or organizational learning (Narayanan et al. 2009).

In general, CV can be understood as the creation of organizational structures fostering the development of new businesses and discontinuous innovation in the context of an established company. Following this, CV creates a "set of organizational systems, processes and practices that focus on creating businesses in existing or new fields, markets or industries—using internal and external means" (Narayanan et al. 2009, p. 59). This enables the exploration of new businesses while simultaneously optimizing existing ones, leading to superior performance of companies in the long term, and is known as organizational ambidexterity (Vanhaverbeke and Peeters 2005). Most recently, CV has experienced high interest in practice leading to a growing number of CV activities in almost all industries. One result of this evolution is the rising number of different organizational forms (Kullik et al. 2018; Selig et al. 2018). In general, these organizational forms can vary from internally oriented CV—e.g., internal start-up teams or intrapreneurship programs—over joint effort with other companies—e.g., joint ventures—to external venturing efforts—e.g., the investments in start-ups through corporate venture capital funds.

With the growing number of CV forms, not only the variety in the organizational design of CV has increased, but also the pursued objectives of initiation and the respective outcomes—e.g., new business creation (Makarevich 2017), access to new markets or new technologies (Lai et al. 2010; Miles and Covin 2002), or attracting/acquiring talents (Hunt et al. 2018; Kohler 2016). These different types of effects and outcomes of CV contradict the "traditional" perspective that stems from the *corporate entrepreneurship* concept and separates *CV*—development of new businesses—and *strategic renewal*—transformation of organizations—from each other (Guth and Ginsberg 1990). Accordingly, an extended view on the effects that CV has on the core organization seems to be needed. This need is reinforced as recent studies have shown that some CV forms do not contribute to the development of new businesses but facilitate the strategic renewal by creating new capabilities and resources for the core organization (Selig et al. 2018).

Research on CV has increased tremendously within the past few years and has contributed to a better understanding of this topic (Kuratko et al. 2015). In general, the research on CV distinguishes three levels of analysis with focus on (1) the core organization, (2) the venture program/unit, and (3) the corporate venture itself (Narayanan et al. 2009). It seems that most of the research to date has focused on the level of the core organization (Narayanan et al. 2009). In addition, there have been several investigations on factors influencing the performance of different CV forms, e.g., top management support (Antoncic and Hisrich 2001; Crockett et al. 2013), organizational culture (Badguerahanian and Abetti 1995), or reward system (Honig-Haftel and Martin 1993). Besides influencing factors, there has been effort on the examination of the concrete implementation of CV forms, e.g., on mechanisms for the separation of CV forms from the core organization (Burgers and Jansen 2008; Gard 2015) or on the individuals working in CV (Kierulff 1979; Selig and Baltes 2017). Although there are several studies on the outcomes of CV, most of them are focusing on the level of the core organization or the venture program/unit level, while the project level of the corporate venture itself has been mostly neglected (Narayanan et al. 2009).

Concluding on this, further research is needed to increase the understanding of the outcomes and effects that CV has on all levels of a company, but especially on the contribution CV has on the venture level (project level). It seems the traditional view on CV which was limited to new business development has to be extended by considering the concepts of strategic renewal and transformation. Additionally, the need for this perspective is increasing as novel CV forms with new characteristics, objectives, and outcomes are emerging in practice (Kullik et al. 2018; Selig et al. 2018). Therefore, this study will contribute to the research on CV by examining internal and cooperative CV regarding their effects on the core organization by comparing different CV forms of two German high-tech companies, seeking to answer how CV forms facilitate new business development and strategic renewal in established companies. Accordingly, the findings can contribute to the research stream of organizational ambidexterity by answering how different forms of CV can facilitate exploration activities in established companies.

2 Corporate Venturing to Strengthen Organizational Ambidexterity

Innovation is recognized as a prerequisite for sustainable competitive advantage (Cefis 2005) and thus serves as a tool for companies' long-term success (Ireland and Webb 2007). Due to social and technological developments like globalization and digitalization (Lyytinen et al. 2016), market environments have become highly volatile, driven by accelerated emergence of so-called discontinuous innovation (Veryzer 1998). These innovations are synonymously termed "disruptive" (Markides 2006) or "radical" innovation (Norman and Verganti 2014). To succeed in such environments, companies need to mirror the changes in the market environment internally by becoming more adaptive. Thereby, market volatility should not be only seen as a threat but also as an opportunity to open up new businesses (Kuratko and Audretsch 2009).

The organizational capability to adapt to volatile environments is discussed in the research on *dynamic capabilities* (Barreto 2010; Teece et al. 1997), which has emerged as one of the most influential theoretical lenses in strategic management research (Barreto 2010; Schilke et al. 2018). According to this concept, the competitive advantage of a company is rooted in the capability to create, extend, or modify its resource base to adapt to changing market parameters (Helfat et al. 2007). A related concept that has experienced high interest in the past years is *organizational ambidexterity* (O'Reilly and Tushman 2013), which describes the capability to develop new businesses while simultaneously optimizing existing ones (Raisch and Birkinshaw 2008). Some scholars argue that organizational ambidexterity can be seen as a subset of dynamic capabilities (O'Reilly and Tushman 2008), while others understand it as a complementary theoretical lens (Birkinshaw et al. 2016) or totally independent from dynamic capabilities (Turner et al. 2013). However, in this study, organizational ambidexterity is understood as a dynamic capability that facilitates the creation of new knowledge and thus the extension or reconfiguration of a company's resource base.

Organizational ambidexterity is defined as "the ability to simultaneously pursue both incremental and discontinuous innovation [. . .] from hosting multiple contradictory structures, processes, and cultures within the same firm" (O'Reilly and Tushman 2013, p. 3). Therefore, the respective company has to be capable of balancing these two learning modes of exploration and exploitation. Exploration is focusing on the creation of new knowledge, which is required to develop discontinuous innovation, while exploitation is associated with the improvement of existing knowledge, as it is the case for incremental innovation (March 1991; Raisch and Birkinshaw 2008). Companies that are successful in applying exploration and exploitation simultaneously have been linked to superior performance in the long term (Burgers and Jansen 2008; O'Reilly and Tushman 2013).

However, achieving organizational ambidexterity poses a challenge to companies, since exploitation and exploration are mutually incompatible (March 1991). Each learning mode shows different requirements in terms of organizational structures, processes, or management behaviors that are facilitating them (Jansen et al. 2005; Lavie et al. 2010; Tushman et al. 2010). Since exploration is characterized by a higher level of uncertainty and long-term outcomes, companies often tend to favor exploitation, which increases the organizational inertia (Lavie and Rosenkopf 2006; March 1991). To overcome the inherent incompatibility of exploration and exploitation, the balance between exploitation and exploration needs to be managed in a certain mode. To do so, two different modes of management are discussed in theory—*structural ambidexterity* and *contextual ambidexterity* (Gibson and Birkinshaw 2004; Simsek et al. 2009).

Structural ambidexterity is often described as a top-down approach (Gibson and Birkinshaw 2004), which focuses on the creation of dual structures that separate exploration from exploitation (Raisch and Birkinshaw 2008). Structural separation has frequently been discussed as being especially well suited for creating discontinuous innovation that naturally bears high potential for conflict (Christensen and Overdorf 2000; Junarsin 2009). From a management perspective, structural ambidexterity poses the challenge of finding the "right" balance between autonomy and control in order to achieve maximum performance for the core organization (Andriopoulos and Lewis 2009; Gard 2015).

Contextual ambidexterity describes the capability to switch between exploration and exploitation within the same entity depending on contextual factors such as culture, leadership style (Wang and Rafiq 2014), and empowerment of employees (Caniëls et al. 2017). Contextual ambidexterity has a strong focus on the individual level (Wang and Rafiq 2014). On an individual level, contextual ambidexterity can be characterized by four types of behavior among employees: (1) taking initiatives outside the "normal" job, (2) seeking for opportunities to combine efforts with others, (3) building internal networks and linkages, and (4) the willingness to have different tasks at the same time (Gibson and Birkinshaw 2004). Some scholars argue that contextual ambidexterity may support the implementation of structural ambidexterity—regarding the concepts as complementing rather than conflicting each other (Andriopoulos and Lewis 2009).

The implementation of organizational ambidexterity may be fostered using corporate entrepreneurship as a tool (Burgers and Jansen 2008). Corporate entrepreneurship can be defined as a "process whereby an individual or a group of individuals, in association with an existing organization, create a new organization or instigate renewal or innovation within that organization" (Sharma and Chrisman 1999, p. 18). This concept has been widely acknowledged as a valid organizational strategy to strengthen entrepreneurial behavior in established companies (Teece 2016). It is frequently linked to a higher performance and long-term survival of companies (Zahra and Covin 1995) in particular in volatile market environments. Some scholars argue that corporate entrepreneurship in general is based on two main pillars, the development of new businesses within established companies—*CV*—and the transformation and rejuvenation of an organization—s*trategic renewal* (Guth and Ginsberg 1990).

Strategic renewal, also referred to as *strategic entrepreneurship*, focuses on the organizational transformation and rejuvenation by questioning the key principles the organization is built on (Verbeke et al. 2007). This is important for companies to match changing market requirements in volatile environment. CV focuses on the creation of new businesses within an established organization through the implementation of separated subunits—corporate ventures (Corbett et al. 2013). However, it has recently been discussed that this traditional separation may be revised, since some CV forms seem to exhibit "lower-than-to-be-expected" potency on creating new businesses, but in contrast "stronger-than-to-be-expected" transformational effects (Selig et al. 2018).

Based on the above definitions, CV aims at implementing structural ambidexterity by separating the new business development (exploration) from the efficiency-oriented core business (exploitation). As a result, these dual structures offer alternative innovation paths within established organizations (Makarevich 2017) and are opening up the organization to absorb know-how from external start-ups (Weiblen and Chesbrough 2015). Thereby, CV covers a broad range of different organizational settings that are summarized in Table 1.

It seems that the variety of CV is still increasing, as in practice established companies experiment with new organizational forms (Burr et al. 2017; Kullik et al. 2018). The growing number of different CV forms increases the need for more research on CV, especially on the venture unit/project level (Narayanan et al. 2009). Several scholars have addressed this issue by offering typologies to categorize and compare the different forms. While Table 1 uses *orientation* (internal vs. cooperative vs. external—Birkinshaw and Hill 2005), other dimensions can be the *initiation* (top-down vs. bottom-up—(Park et al. 2014), the *objective* (strategic vs. financial—Basu et al. 2011), or the *innovation flow* (outside-in vs. inside-out—Weiblen and Chesbrough 2015). However, it has been stated that a lack of a harmonized typology is one key limitation in current CV research (Gutmann 2018; Narayanan et al. 2009).

In that regard, the concept of *entrepreneurial intensity* offers an alternative perspective for categorizing the different CV forms by using their *frequency* (how often does it take place) and their *degree of entrepreneurship* (how innovative, risky, and proactive are the activities pursued) (Kuratko and Audretsch 2013). Following this notion, recent discussions indicate that a combination of a lower degree of entrepreneurship with a higher frequency may have a stronger effect on organizational transformation rather than on the creation of new business. Such combinations may, for example, be present in internal corporate accelerators or internal corporate incubators (Selig et al. 2018). Generally, it seems valuable to give greater attention to the various effects and outcomes of CV in order to categorizing them better.

Based on the literature review, the following propositions (P) are formulated, aiming at answering the overall research question:

P1 *CV supports not only the development of new businesses but also the strategic renewal of established companies by creating new capabilities/resources that are transferred back to the core organization.*

P2 *Internal-oriented CV forms with a high degree of entrepreneurship and a low frequency support the organizational transformation mainly through the*

Table 1 Overview of CV forms

CV form	Description	Orientation
Internal corporate ventures (Makarevich 2017)	Start-up type of organizations within established companies that focus on the creation of new businesses based on more radical type of innovation	Internal
Internal corporate accelerators (Selig et al. 2018)	Time-limited, cohort-based programs, which focus on the fast validation of innovation ideas from employees	Internal
Internal corporate incubators (Marcus and Zimmerer 2003)	Separated units that provide a supportive environment for the development of internal innovation ideas from ideation to commercialization	Internal
Joint ventures (Kogut 1991)	New ventures build by minimum two companies with the rationale to combine complementary capabilities reduce the individual investment and risk	Cooperative
External corporate ventures (Parhankangas and Arenius 2003)	New ventures formed by one company based on ideas born within that company, which are supported in their founding by that company parent	External
External corporate accelerators (Weiblen and Chesbrough 2015)	Corporate programs that support external start-ups for a limited time with company's resources and mentoring to get access to ideas and concepts	External
External corporate incubators (Eckblad and Golovko 2016)	Programs that offer similar support activities than external corporate accelerators but for a much longer duration and take a higher equity stake	External
Corporate venture capital (Benson and Ziedonis 2009)	Investment funds build from corporate's capital that invests in external start-ups with strategic and/or financial objectives	External
Mergers and acquisitions (Jemison and Sitkin 1986)	Transactions of ownership from one company to another company. In the context of corporate entrepreneurship, start-ups are often bought to adjust a company's business or technology portfolio	External

Source: authors' own table

development of new businesses and the resulting transformation effects that occur for their core organization.

P3 *Internal-oriented CV forms with a low degree of entrepreneurship and a high frequency support the organizational transformation mainly by creating new resources and capabilities, but not through the development of new businesses.*

3 Research Methods

3.1 Data Sample

The study examined and compared different CV forms by following a qualitative research strategy. The data sampling followed a purposive perspective to ensure that the cases were relevant for answering the research questions (Bryman and Bell 2015). The sample contained the different CV forms of internal corporate accelerators, internal corporate ventures, external corporate ventures, and joint ventures and, therefore, covered a broad range from initiatives with high entrepreneurial level and low frequency to initiatives with low entrepreneurial level and high frequency.

All cases were investigated within two German high-tech companies, one from the telecommunication and one from the automotive industry. Both industries are faced with intensive market changes due to digitalization and other major technological changes. While the telecommunication industry has already experienced radical changes coming along with the rise of the (mobile) Internet, the automotive industry is in the beginning of a radical transformation through electrical engines, autonomous driving, and the mobility-as-a-service trend. Both have in common that the respective companies acting in this industry must develop discontinuous innovation and ways of managing them, e.g., by using different forms of CV.

The different CV forms in this study were accompanied by the researchers for more than two and a half years. The data sample contains 17 interviews that were conducted on-site between June 2015 and March 2018. Twelve interviewees are male and five female and the average age (Age_{M}) is 39 years ($Age_{MIN} = 26$; $Age_{MAX} = 55$). The sample consists of two interviews with the manager of the internal corporate accelerator, *corporate business angel* (Selig and Baltes 2017), seven interviews with participants of the internal corporate accelerator programs (five team leaders, *intrapreneurs* (Camelo-Ordaz et al. 2012), two team members), one interview with an internal start-up coach, as well as five interviews with the leaders of corporate ventures, *corporate entrepreneur* (Kierulff 1979; Selig et al. 2016).

3.2 Data Collection

Regarding the data collection, a triangulation of information is recommended (Yin 2013). To meet this criterion, the data was complemented with field notes, companies' information, as well as visits of pitch events including several informal conversations with participants and the organizing committees. Additionally, follow-up calls were made to enrich the data regarding the transformation effects. Within the CV forms, different perspectives were collected and analyzed (corporate entrepreneur, corporate business angel, intrapreneur, team member, coach) to reduce biases of the interviewees. All interviews were recorded and transcribed on

Table 2 Structure of the interview guide and sample questions

Level of transformation	Investigation focus	Sample questions
Intrapersonal level	Personal background Experiences Motivation Skills Competencies Traits ...	What is your name/age/marital status/...? What have you done before you came to this job position? What is your motivation to work in such an environment? In your opinion, what are the most relevant skills/competencies/... in your job position and according to your tasks? How would you describe you as a person, risk-averse/venturesome/need for a certain degree of autonomy/security?
Interpersonal level	Team creation Leadership style Conflicts Communication Decision making Role Models ...	What roles are part of the respective CV form? How did the team creation work out? How does the decision process look like? Which leadership style takes place within the CV form? Did some conflicts occur over time and course did they take? What were the most recent conflict triggers? Are there some influencers/deciders within the decision process that have a significant impact on the decision? How do you manage stakeholders?
Organizational and project level	Organizational context Target setting Access to shared services Organizational interface Spill-over effects ...	How does the leadership differ from your experience in the core organization or other companies you were working in? Where does your work in the internal start-up team differ from your former job? Where was the idea born? What are enablers/disablers for your work/for the initiative? How was the collaboration with departments within the core organization? Which resources/shared service were provided by the core organization?

Source: authors' own table

548 pages that represent 1168 min of recorded material (IM). The average interview duration (IM_M) was 69 min, with the shortest (IM_{Min}) interview being 44 min and the longest (IM_{Max}) 112 min. These transcribed interviews served as the data basis for the ongoing data analysis.

To ensure that all relevant aspects were covered, the researchers used semi-structured interviews with open-ended questions. This method allows the researcher to discover and follow up on new insights that arise during the interview (Bryman and Bell 2015). The structure of the interview guideline followed the three levels of organizational transformation (Crossan et al. 1999), illustrated in Table 2.

3.3 Data Analysis

A qualitative research design was chosen as there is little known about transformational effects of the different CV forms on their core organization. The research made use of an abductive approach that combines inductive and deductive elements. Therefore, the transcribed interviews were coded by the one author following grounded theory principles to reveal key themes and patterns on how the different CV forms support the organizational transformation. Critical text passages and the results were discussed with all authors. The analysis focused on changes within the resource base of the core organization and on resources that were created in the respective CV form. The creation and transfer of resources was selected as it has been recommended as an outcome measure for dynamic capabilities (Zahra et al. 2006).

The initial inductive approach was complemented by combining the codes from the open and selective coding phase with existing codes from previous studies on internal corporate accelerator (Selig et al. 2018). This deductive element ensures that the results of this study are embedded and linked to relevant preliminary work (Gioia et al. 2013). Thus, the final codebook consists of codes from the applied coding frame that were confirmed and enhanced through the open and axial coding process (Corbin 1990). Table 3 represents the applied coding frame and gives a short description on each code.

4 Results: Two Types of CV Forms with Different Effects on the Transformation of the Core Organization

The conducted interviews focused on the interface and on the transformation effects between the core organization and different CV forms, namely, internal corporate accelerator, internal corporate venture, and joint venture. The analysis of the interviews focused on changes in the resource configuration caused by the different CV activities. This is justified since the related concepts of dynamic capabilities and organizational ambidexterity are closely linked with learning, which results in the creation of new capabilities and resources. Resources as an outcome measure in this context are recommended in the literature (Birkinshaw et al. 2016; Zahra et al. 2006) and have been tested in prior research (Selig et al. 2018). Table 4 illustrates the transformation effects that occurred within core organizations by revealing the code frequency of each effect. Further, the combination of interview data and contextual data allowed a categorization of the investigated case studies. Thereby, the examined CV forms can be categorized as follows:

1. *Focused corporate venturing concepts*: CV forms that are initiated to implement one dedicated idea, typically top-down driven. In this study, this category consists of internal ventures and joint ventures. These CV forms can be characterized by a

Table 3 Transformational effects of CV forms on the core organization that were analyzed in the course of this study

Transformation dimensions	Transformation effects	Description
Operational renewal	Creation of new processes	Tensions and conflicts that arise between the core organization and the CV initiative lead to the adjustments of existing processes to become more innovation friendly
	Creation of operational flexibility	CV forms support "shortcuts" or the acceleration of existing processes due to (a) goodwill on a more informal level or (b) power since the project has a high strategic relevance
Entrepreneurial employees	Creation of an entrepreneurial skill set	Entrepreneurial skills that are thaught due to coaching/mentoring and the new working methods within the CV initiative, which increase customer centricity and entrepreneurial working styles
	Creation of an entrepreneurial mind-set	Entrepreneurial activities throughout the different CV forms lead to more entrepreneurial thinking and acting employees. Support of the top management is a signal that this behavior is appreciated
	Sensitization of top management	High contact of top management members to entrepreneurial projects through their roles as jury members, corporate sponsors, or mentors leads to a sensitization for entrepreneurial topics
Entrepreneurial multiplicators	Creation of entrepreneurial role models	Participants of CV forms can become role models for their colleagues, which e.g. motivates them to work on entrepreneurial ideas as well
	Internal coaches and mentors	The creation of a network of coaches and mentors that have experienced responsible positions in CV initiatives and are willing to share their know-how
	Creation of an entrepreneurial community	Employees that are working/or have worked in CV forms maintain linkages among other employees in similar environments
Innovation platforms	Creation of innovation exchange platforms	Virtual or physical exchange platforms for entrepreneurial topics. For example, demo days, pitch events, or an online platform in the intranet
	Creation of exposure to sponsors	Specialized events or institutions, e.g., innovation boards, offering direct access to corporate sponsors with the decision power to support innovation
Start-up ecosystem	Access to start-up ecosystem	Spin-out options for employees who are willing to leave the company to work on their idea. Increases credibility as a player in the start-up ecosystem
	Strategic options	Sometimes the strategic fit is not clear or is changing over time. A partnership to former spin-offs offers future strategic options for investments
New business creation	Access to a new customer group	The creation of a new product or service offer that leads to a totally new, often strategic relevant customer group

(continued)

Table 3 (continued)

Transformation dimensions	Transformation effects	Description
	Creation of new businesses	New, often radical businesses that are not directly linked to the company's core business are typically implemented through corporate venturing
	Creation of new features/services	Improvement of the existing products or services by adding new features that were developed in CV initiatives, to increase customer satisfaction
Know-how creation	Creation of technological knowhow	New knowledge around technologies or product features that have not been used within the company's context
	Creation of customer insights	New know-how about customer needs and market trends, as a basis for the creation of new products and business models
	Creation of methodical know-how	New working methods and styles like design thinking, lean start-up, etc., that are increasing the customer centricity and thus the product/market fit

Source: authors' own table

high level of entrepreneurship but a low frequency, according to the entrepreneurial intensity construct.

2. *Broad corporate venturing concepts*: CV forms that are initiated to achieve a superordinate objective, such as increasing innovativeness in general, which is in the first place independent of the respective ideas. In our sample, they are represented by internal corporate accelerators, which are characterized by a low degree of entrepreneurship but a high frequency.

The results show that the two categories, focused CV forms and broad CV forms, differ regarding their transformation effects toward the core organization. Focused CV forms have the strongest impact on the core organization due to the creation of new, strategic relevant businesses, new products and/or services, and new customer groups. Whereas broad CV forms have a wider impact regarding the organizational transformation, especially when it comes to changes on the individual level, e.g., imparting entrepreneurial skill- and mind-set, sensitizing top management, and creating exchange platforms for entrepreneurial employees. Despite the differences in transformation effects between the two CV categories, the data show no significant difference with respect to different industries. In the following, the results from the respective transformation dimensions are explained in detail and underlined by a representative quote from the interviewees for each dimension.

The *operational renewal* dimension describes effects on the core organizations' structure and processes, which are caused by the work and interaction between the CV form. The focused CV forms, which are typically initiated top-down and have a strong corporate sponsor, show that the change in the governance of the core organization is mainly achieved over institutional power, whereas broad CV forms

Table 4 Transformational effects of categorized CV forms on the core organization

Transformation dimensions	Transformation effects	Focused CV forms	Broad CV forms
Operational renewal	Creation of new processes	X	X
	Creation of operational flexibility	X	X
Entrepreneurial employees	Creation of an entrepreneurial skill set		X
	Creation of an entrepreneurial mind-set	X	X
	Sensitization of top management		X
Entrepreneurial multiplicators	Creation of entrepreneurial role models	X	X
	Internal coaches and mentors		X
	Creation of an entrepreneurial community		X
Innovation platforms	Creation of innovation exchange platforms		X
	Creation of exposure to sponsors		X
Start-up ecosystem	Access to start-up ecosystem		X
	Strategic options		X
New business development	Access to a new customer group	X	
	Creation of new businesses	X	(X)[a]
	Creation of new features/services	X	X
Know-how creation	Creation of technological know-how	X	X
	Creation of customer insights	X	X
	Creation of methodical know-how		X

Source: authors' own table
[a]The success of the business creation is disputable. One business was still in a very early stage and another business was shut down after 2 years

use efforts of persuasion and goodwill to achieve changes in the processes and structures of the core organization.

> Ultimately, by being relatively active in the innovation environment, we have had many advocates who have said that the topic is exciting, so that we and our colleagues are now benefiting more and more from it. We've created a process that allows young start-ups that don't have a long history to dock here somehow, so we have a form of secure collaboration through the purchasing process.

The *entrepreneurial employees'* dimension is mostly influenced by broad CV forms. The short duration in combination with high frequency offers a bigger number of employees the opportunity to work on entrepreneurial projects. In both cases, the employees had access to coaches and mentors that supported them with training on entrepreneurial methods. Through the embedding of higher management, e.g., as jury in a pitch event, the top management level experiences frequent exchange with entrepreneurial topics and employees.

The [program] says, first of all, we are a training camp, most ideas fail, but to work on an idea ourselves, to talk to the customer ourselves, to experience such a speed which is possible as [name] says, just changes the problem solving strategy in normal business, you simply look differently at what you have considered normal in everyday life.

The *entrepreneurial multiplicators'* dimension shows that focused and broad CV forms lead to the creation of entrepreneurial role models within the company. Broad CV forms additionally support the development of entrepreneurial assets like a pool of coaches and mentors that support these innovation projects by sharing their experience or a community of like-minded people who are interested in entrepreneurship and innovation topics.

So now, without exaggerating, the founding partner and me, we now have a cult status. People come up to us and ask; hey, can you give us some tips? Or people come to us with ideas; look, is that something like that? Can you imagine something like that working? How did you get into the Accelerator?

The dimensions *innovation platforms* and *start-up ecosystem* are only affected by broad CV forms. The creation of platforms that facilitate the exchange between entrepreneurial employees on their ideas and other innovative topics was a key task of the management of the broad CV forms. In one case, the platform was also used to connect the company to the local start-up ecosystem.

So once, twice a year, or three times a year there are Startup Days. It's such a format, every employee can come there for three days. With an idea, or without an idea. Teams are formed around the most prominent, or the most popular ideas, according to the law of the feet. [. . .] Then a colleague [name] joined me. And worked on it for three days. And when those three days somehow went through, we just looked at each other and said what to do with it now. We have received relatively good feedback. Do we want to go on with that? We said, yes, well, let's just carry on a little bit.

The dimension *new businesses development* shows in contrast to the prior dimensions a strong influence by focused CV forms. While the broad CV forms often addressed digital services or the development of a feature, the focused CV forms typically had the task to develop a new business.

In the end, we started to search and recruit a tekkie, who then transformed the whole topic into a Ltd. (controlled by the core organization), so that we also had a corporate structure that allowed us to operate independently on the market. [. . .] We then installed over five hundred [products] in selected stores for [company name], right down to the product group level.

The dimension *know-how creation* is positively influenced by both types of CV. The work on innovative projects leads to the generation of knowledge about new technologies and customer needs, independent from the CV form. Broad CV forms offer training and coaching for their participants, which explicitly supports the creation of methodical know-how, e.g., design thinking or business model canvas.

This simply "think outside the box" is something that's good for you. And also, the methods you learn: Simply approach the customer right away. Not to paint a nice PowerPoint slide again, but just to do it. And think about it and also make rough assumptions and continue to work with them. We [in the R&D] don't do that otherwise.

Regarding the literature-derived propositions, this research reveals that CV forms support the creation of new businesses as well as the transformation of the core organization—strategic renewal. In this respect, the different CV forms show different transformation effects within the core organization as described above and summarized in Table 4. In the following, the respective P are examined based on those results.

P1 This research shows that CV forms support the creation of new businesses as well as the transformation of the core organization—strategic renewal. Thereby, the different CV forms show different transformation effects within the core organization (Table 4). According to this study, CV forms can be categorized into *focused CV forms*, which mainly support the creation of new businesses, and *broad CV forms*, which have a strong impact on the overall transformation and renewal of an organization.

P2 CV forms with a high degree of entrepreneurship but a low frequency, summarized under the term focused CV forms, show a strong focus on the creation of new businesses. The creation of new businesses, as a primary goal, may lead to transformation effects on other dimensions; however, these effects are not the main reason why these CV forms are initiated. CV forms with a high degree of entrepreneurship typically experience a stronger separation from the core organization by creating dual structures, to decrease resistance and tensions and to increase the speed of the venture.

P3 Internal-oriented CV forms with a high frequency but a rather low level of entrepreneurship are not well suited to create new businesses. This is especially the case for CV forms with a limited duration and no predefined follow-up structures. However, these forms support the organizational renewal by creating new resources and capabilities, which are transferred back to the core organization (transformation effects). Due to their high frequency, they support the creation of a critical mass of entrepreneurial potential and thinking within the core organization, even though the overall level of entrepreneurship of the ideas is rather low.

5 Discussion: Renewing Established Companies in Times of the Digital Transformation with CV

In times of the digital transformation, the organizational capability of adapting to market changes and implementing radical innovation becomes more and more relevant. Corporate entrepreneurship and CV in particular offer a broad range of different managerial tools to manage transformation and to create discontinuous innovation to be successful in the long term. This chapter has examined how different types of CV contribute to the organizational renewal and thus strengthens the understanding of the effective use and management of CV. The investigated CV forms from this study can be subdivided into two categories: (1) focused CV forms and (2) broad CV forms. This categorization supports earlier findings arguing that CV supports not only the creation of new businesses but also the strategic renewal of companies and gives practical implications on which CV forms may be more suitable for the respective objective.

Focused CV forms (high level of entrepreneurship but low frequency) seem to mainly support the creation of new businesses, while *broad CV forms* (low level of entrepreneurship but high frequency) have a stronger impact on the overall transformation and renewal of an organization. Following this, it seems to be recommendable for a company to simultaneously operate several CV forms with different manifestations (high level of entrepreneurship/low frequency or low level of entrepreneurship/high frequency) since they increase the overall entrepreneurial intensity within the company.

Focused CV forms typically have a stronger impact on the business development but, at the same time, are more resource intensive and have a higher potential for conflicts. These conflicts are often based on competence disputes or cannibalizing effects. Accordingly, companies should only implement a specific number of these initiatives to not overstress the core organization. Finding the right balance can be understood as one element of ambidextrous management. Regarding their implementation, a structural separation is recommended to reduce the potential for conflicts. At the same time, this requires a good management to ensure strategic alignment of the corporate venture and to facilitate synergy effects.

Broad CV forms, which are characterized by a lower level of entrepreneurship but a high frequency, show a higher level of integration into the core organization and a lower potential for tensions and conflicts. Integration seems to be a crucial element since some aspects are based on voluntariness and goodwill, e.g., the internal mentors, exemption from employees, or adjustment of processes. The lower conflict potential could be rooted in the circumstance that nascent ideas often experience much lower attention than more mature ideas, especially when the latter ones are officially launched as a corporate venture that is equipped with resources and often closely linked to the top management of a company. Affecting the entrepreneurial education of employees and their mind-set, broad CV forms seem to be a useful tool for human resource management as well.

Even though all investigated CV can be characterized by a structural separation and consequently follow the structural ambidexterity approach, some elements identified in this study indicate similarities to the contextual ambidexterity approach, especially to the ambidextrous behavior of employees. This behavior is characterized by four elements: (1) employees take the initiative and look for opportunities beyond their daily business, (2) they are highly cooperative and seek to partner with others, (3) they are good in building internal network, and (4) they are comfortable in doing several things in parallel (Birkinshaw and Gibson 2004).

By comparing these four types of ambidextrous behavior to the effects of the broad CV forms, several commonalities can be identified. To participate, e.g., in an internal corporate accelerator program employees have to (1) apply with an idea that is typically more radical than the innovation in the R&D pipeline; (2) partner with other and build a team to work on the idea; (3) allocate supporters and resources, which requires a good network; and (4) work in their daily job and in parallel on the idea before they are accepted in the program, and occasionally the programs are part-time, which means they must work on several topics simultaneously. Looking at these similarities, it seems to be reasonable to define broad CV forms as hybrid-ambidextrous.

Prior research on contextual ambidexterity has shown that the resulting "explorative" behavior on the individual and organizational level is facilitating the implementation of structural ambidexterity, e.g., in the form of corporate ventures. Following this, broad CV forms may serve as an enabler for entrepreneurial activities and the implementation of focused CV forms. Especially broad CV forms seem to strengthen ambidextrous thinking among employees and top management and support the development of an *ambidextrous mindset* within the whole organization, which means that independent of whether employees work in a more exploitation-oriented or exploration-oriented environment, they have a deep understanding of the necessity of both modes and the associated paradoxes.

Regarding the challenges that occur in the context of the digital transformation, CV offers interesting opportunities for companies to master their renewal. CV supports companies in developing digital businesses, value adding digital services or product features, and additionally new digital skills whether on a technological or methodical side. This broad range of different effects makes CV not only a valid tool for innovation management or new business development but also for human resource management, e.g., as a tool for entrepreneurial education or employer branding.

Another observation that was made during this study is that broad CV forms are especially popular in German-speaking countries. A prior literature review on corporate accelerators and corporate incubators has revealed that 15 out of 23 publications stem from German-speaking authors (Selig et al. 2018). This resonates with findings that Germany is global number two when it comes to the number of corporate accelerator programs being established (Kanbach and Stubner 2016). An initial interpretation may lead to a consideration of cultural differences, a high share of family-owned business (Hatum and Pettigrew 2016), as well as differences in labor market regulation as root causes (Soskice 2006). For example, it would be both more feasible and common to exchange larger parts of a company's workforce in the USA in order to fuel an organizational transformation while in Europe; in particular e.g. in Germany, it would be less feasible (comparably lower unemployment of skilled employees, high legal hurdles to lay off larger number of employees) and less common (any attempt usually resulting in serious worker's union protests). Recent interviews[1] in the Silicon Valley support this assumption. Managers from German subsidiaries have declared spill-over and transformation effects from CV activities as highly relevant, while managers from US companies ranked them as rather unimportant for their work.

[1] Interviews that were conducted in the course of a research exchange in 2016, 2017, and 2018 with managers of CV initiatives from German and US companies based in the Silicon Valley.

5.1 Limitation of the Study

In the nature of research, the emergence of limitations is inevitable. The presented results in the field of CV are limited in their generalizability and applicability within practice. Limitations occur in terms of the inclusion or exclusion of cases regarding the sampling. By focusing on only two case companies, the question of generalizability arises, and therefore, the transferability of the results is limited. However, both companies are embedded in industry environments that are characterized by a high degree of environmental dynamics and the results were reproducible independently of the respective industry. This is possibly rooted in the fact that all projects that were investigated in this study had a strong focus on digital topics and software. The results may would have been different when it comes to hardware-intensive innovation projects; as the products differ much stronger in hardware than in software. In this respect, the limitations toward generalizability must be further elaborated by investigating a broader range of CV projects that include hardware and software innovations.

The data collection and thus the sample are inconsistent in terms of guaranteeing a holistic perspective on the transformation effects of internal-oriented CV forms on the core organization. For example, due to limitation of access to data, interviews were mainly conducted with members of the corporate ventures. Therefore, the transformation effects are described one-sided and allow space for social desirability, narratives, and interpretation (Bryman and Bell 2015). These interferences are strengthened through the retrospective view (Crossan et al. 1999). One possible solution to this issue could be a more longitudinal study that is accompanying the discontinuous innovation projects from the ideation stage until the commercialization. This may include the investigation of several CV forms since ideas that were started in an internal corporate accelerator can be continued as internal venture, as joint ventures but also within the standard R&D process. Furthermore, an extended sample that covers more companies and more different CV forms seems to be required.

By applying qualitative research methods without longitudinal elements, follow-up interviews within the core organization as well as with other CV members would be useful to find out which of the identified transformation effects actually have a sustainable effect. Thereby, some of the effects came not directly to bear at the interface between the CV form and the core organization. Thus, further interviews with the departments and responsible persons within the core organization, which were directly affected, would be useful to further strengthen the results. The results reveal that a variety of transformation effects is arising from internal-oriented CV forms. However, it is not clear which effects are most relevant for the strategic renewal of a company. To gain a more holistic understanding, it seems to be relevant to additionally investigate external-oriented CV forms.

The use of a prevailing coding frame for the data analysis and, thus, combining inductive and deductive elements can lead to bias according to the application of grounded theory. An independent coding cannot be guaranteed. Therefore, further research is needed to confirm or falsify the presented results. For future investigations on transformation effects of CV, it seems to be valuable to take a deeper look into related streams like strategic renewal or organizational learning. This seems to be important, since this study was using a CV perspective which may be insufficient to explain transformation and renewal in a more holistic manner.

5.2 Managerial Implications

Based on the findings of this research, the following managerial implications can be drawn to support the effective use of CV as one managerial tool to master the renewal and the transformation of an established company:

- Both focused and broad CV forms can be used to achieve organizational ambidexterity. However, it is important for management to gain a more differentiated understanding about when to use which CV form.
- Focused CV forms are a good tool to implement already validated ideas. Depending on the characteristics of an idea, different focused CV forms are worth to be considered. Ideas that require a totally new set of capabilities are possibly better suitable to be implemented as a joint venture or require a high level of external employees. Ideas that are combining existing and new technologies require a high level of integration that can be achieved with internal ventures, while ideas that are independent from current knowledge base can work better as external venture.
- The effectiveness of organizational transformation will be increased by the parallel implementation of several CV forms as synergy effects take place. Broad CV forms strengthen the entrepreneurial orientation and behavior within the core organization, which can increase the acceptance toward more radical innovation that are implemented within the focused CV forms.
- Even though the operation of several CV forms seems to be beneficial, it is critical to understand how much exploration can be handled by the core organization, to not overstress them, which typically causes resistance.
- Broad CV forms support the organizational transformation through the creation of entrepreneurial capabilities, mind-sets, and resources that are frequently reintegrated into the core organization. This creation of entrepreneurial thinking and acting leads to the creation of an *ambidextrous mind-set*, a mutual understanding regarding the relevance of exploration and exploitation, supporting the balance and acceptance of the different modes.
- Broad CV forms can be understood also as HR mechanism, since they support the creation of entrepreneurial skills and entrepreneurial thinking. Furthermore, they seem to have positive effects regarding employee retention and employer branding, since entrepreneurship/intrapreneurship is an attractive topic for young talents, especially for the so-called millennials.

- If broad CV forms are used as a HR tool, they have to be measured and evaluated differently than when these forms are used to create innovations. Therefore, the management must be clear about which effects shall be achieved and how these can be measured.
- Teams that are validating an idea in a broad CV form show a *shared leadership* behavior. In contrast to this, the leadership in focused CV forms is concentrated on one or maximum two leaders. This requires a shift of leadership style and must be considered when an idea from a broad CV form is promoted to be executed as a focused CV form.

5.3 Future Research Agenda

In relation to the abovementioned limitations and managerial implications of this study, several opportunities for future research arise.

This study shows that the investigated CV forms can be classified into two categories, distinguished by their degree of entrepreneurship and their frequency. This classification was helpful to understand differences regarding the effects and outcomes that the different CV can have. Since the data sample of this investigation did not consist of external-oriented CV forms such as external corporate incubators or corporate venture capital, it remains unclear if the entrepreneurial intensity construct is suitable as dimensions to categorize the whole range of different CV forms. Future research may further elaborate on this as a way to categorize CV regarding the transformational effects and outcomes. From a practical view, it seems important to focus more on effects and outcomes of CV to define a harmonized typology.

Besides that, this study supports the assumption that structural ambidexterity and contextual ambidexterity can be understood as complementary approaches instead of contrary ones, since the results show that the implementation of broad CV forms (structural ambidexterity) is influencing and fostering ambidextrous behavior among the employees (contextual ambidexterity). Future research may address the question if combining different CV forms strengthen organizational ambidexterity even further and how a portfolio of different CV forms should look like to facilitate this organizational capability. Therefore, it seems highly relevant to investigate more on transformational effects and potential synergies among different CV forms.

To better understand the impact that CV has on organizational ambidexterity, it may help to look at ambidexterity in particular at the underlying learning modes more differentiated. The development of a new business typically requires the exploration of new knowledge. However, this knowledge can strongly diverge. For one business a company may have to explore "just" a new technology, while for other businesses a totally new market with new customer and other sales channels has to be explored. Using a more differentiated view that consists of different types of knowledge (e.g., technology, market, customer, work method, or business model) could deliver valuable insights on how to manage the respective projects and maybe which CV is most suited.

Concluding on this, CV will become more and more relevant for established companies as volatility of markets seems to further increase. From an organizational ambidexterity perspective, it seems worthwhile to implement different CV forms in order to achieve different effects that range from entrepreneurial training for employees, to the creation of more agile and innovation-friendly processes, to the development of new businesses. For being effective, a deeper understanding on how CV is creating value, which goes beyond new business development, is required.

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The Internet of Things in a Business Context: Implications with Respect to Value Creation, Value Drivers, and Value Capturing

Victor Wolf, Jutta Stumpf-Wollersheim, and Lukas Schott

Abstract The Internet of Things (IoT) is a network that connects devices and everyday objects to exchange data. IoT solutions consist of two elements, namely, the "thing" itself and its digital addition. Thus, these solutions deliver value based on a physical "thing"-based function and on a digital, connected IT-based function. Due to this hybrid nature of the IoT construct, firms have to rethink how to create and capture value. However, we still know very little about the influence of the IoT on value creation, value drivers, and value capturing in a business context. We conceptually analyzed the potential impacts of the IoT on value creation, value drivers, and value capturing. With regard to value creation, we suggest that the characteristics of IoT solutions (the independence of the information stream and its accessibility) result in new possible ways of creating value and in specific drivers of value creation in IoT environments, namely, efficiency, network effects; customization, servitization and value co-creation, shared value drivers, and novelty. With regard to value capturing, we suggest that the hybrid value construct enables the value stream of digital information to be independently marketed, thereby allowing for completely new ways of capturing value in the IoT context.

Keywords Internet of Things · Hybrid structure · Value creation · Value drivers · Value capturing

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1 Introduction

Investigating how the Internet of Things (IoT) (i.e., the interconnection of physical and virtual "things" based on existing and evolving interoperable information and communication technologies, ITU 2012, p. 1) influences value creation, value drivers, and value capturing in a business context is important for the following reasons. First, in a traditional business environment, value creation was (and still is) directly related to the product itself. By contrast, the IoT adds value by enabling additional services based on digitalization. For example, firms that traditionally sold printers might offer smart printers that reorder printing cartridges themselves. Thereby, the firms do not solely offer the printer (physical value) but also offer a service, namely, the service of delivering printing cartridges at the appropriate moment (digital value). Due to such differences between traditional and IoT business environments, investigating potential changes concerning value creation, value drivers, and value capturing is of utmost importance. Second and relatedly, the IoT connects different industries and thus represents the basis for new business models based on value co-creation and value networks. Spanning the borders of firms and industries will presumably increase competition, which will, in turn, force firms to rethink their established business models and market assessments (Turber et al. 2014). Accordingly, changes with respect to value creation, value drivers, and value capturing appear to be very likely in IoT business environments. Third, a Gartner study forecasts that the number of connected "things" will increase from 8.3 billion in 2016 to over 20 billion by just 2020 and projects the corresponding endpoint spending related to these units to then reach nearly 3 trillion US dollars (Gartner 2017). Given that the IoT offers a significant potential for businesses to create and capture value (Openshaw et al. 2014), such forecasts underline the importance of gaining a better understanding of firms' value drivers and of how firms create and capture value.

Previous research on the IoT has primarily focused on the technological aspects of the IoT (Del Giudice 2016). For example, prior research has looked at how the IoT can be used to integrate intelligent interfaces in the information network (Atzori et al. 2010; Berman and Kesterson-Townes 2012), how the IoT can improve efficiency in the use of resources (Palacios-Marqués et al. 2015), or how the IoT can optimize production systems, services, and decision-making processes (Iglesias et al. 2013; Del Giudice and Straub 2011). Additionally, there are few contributions that identify the drivers of value creation in IoT solutions (e.g., Fleisch et al. 2017; Mejtoft 2011). However, the "IoT is not well presented in management literature" (Whitmore et al. 2015, pp. 269–270), and we still know very little about the influence of the IoT on value creation, value drivers, and value capturing in a business context (Westerlund et al. 2014).

We seek to address this noticeable research gap by conceptually analyzing the potential impacts of the IoT on value creation, value drivers, and value capturing in a business context. Based on theoretical considerations concerning the IoT and value creation, value drivers, and value capturing in traditional business environments, we suggest potential influences of the IoT in a business context. We end by discussing our suggestions, implications for theory and practice, and suggestions for future research.

2 Theoretical Background

2.1 The Internet of Things

In recent years, the IoT has grown in relevance and became a leading theme in academic, professional, and popular discussions (Fleisch 2010). The term "IoT" is often used very broadly to refer to the network of things itself, the underlying technologies (e.g., sensors, actuators, network infrastructure), and the applications built atop that technology (Miorandi et al. 2012). The main principle behind the IoT is the notion that, based on new sensor and networking technology, the integration of digital elements enables physical objects to gain additional characteristics of digital technology (Yoo et al. 2012). These characteristics include the capability to be uniquely and individually addressable, interoperable, programmable, and communicable based on standard communication protocols (Chan 2015; Glova et al. 2014). Thus, the IoT bridges the gap between the physical world and its representation in information systems (Haller et al. 2009). Conceptually, the IoT architecture can be described based on the prevalent four-layer modular architecture of digital technology (ITU 2012) (see Fig. 1).

In the first layer, the *device layer* (often referred to as the sensing layer), sensors and actuators measure physical real-world events, transform them into digital

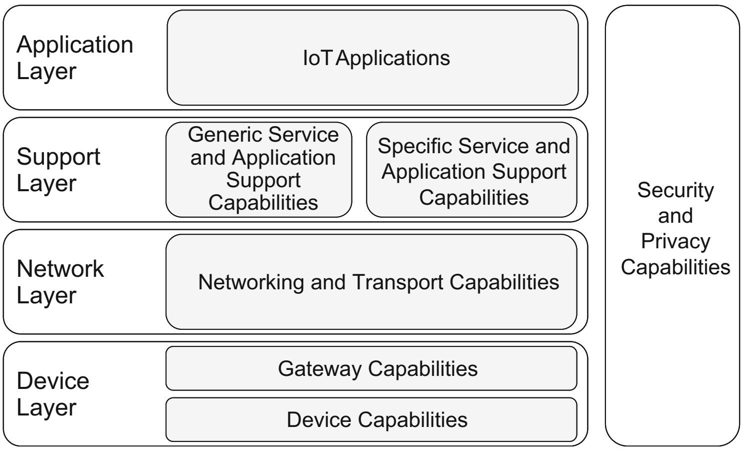

Fig. 1 Layer architecture of the IoT. Based on the "IoT reference model" (ITU 2012, p. 7)

information, and process this information in real time (Ju et al. 2016). The quantity and quality of sensors have a major impact on the ability to acquire the required data in the required granularity (Fleisch 2010). The cost of deploying and maintaining the required sensing infrastructure is therefore one of the key factors influencing the feasibility and economic usability of IoT technology. The second layer, the *networking layer,* fulfills the function of providing a robust network structure that meets the high-performance requirements for low latency, high bandwidth, security, and a high number of concurrent users to transmit information (ITU 2012). The third layer, the *support layer*, handles the main functions related to data processing. This layer provides data analytics for both aggregated data and real-time streaming data, depending on the intended use case (ITU 2012). The fourth layer, the *application layer*, provides the user interface with specific applications. This layer is one representation of the so-called future Internet, which is the basis for a web-based service economy, consisting of service platforms and services that are offered on that platform. The types of services can range from high-level business services to low-level sensor services (e.g., aggregated services or the read-out of a certain sensor state) (Haller et al. 2009).

Such a layered architecture is advantageous for several reasons. First, it enables design decisions for the components of each layer to be made individually and with minimal consideration of other layers, while standardized communication protocols assure the compatibility between layers (Yoo et al. 2010). Second and relatedly, the modularity resulting from the decoupling of the layers and their components in the architecture allows multiple stakeholders in the network (i.e., the focal firm, suppliers, customers) to contribute across all layers (Turber et al. 2014). The layered modular architecture enables the possibility of serving as a platform on one layer while serving as a component or product on another (Yoo et al. 2010). Therefore, each layer can itself be seen as a source of value creation (Turber et al. 2014).

From a management perspective, however, a less detailed consideration of the IoT concept appears more favorable. Fleisch et al. (2017) suggest considering the IoT as a hybrid construct that consists of two elements, namely, the "thing" itself and its digital addition. The value of the IoT solution that is delivered to the customer thus comprises a physical "*thing*"*-based function* and a digital, connected *IT-based function*, i.e., a digital service (see Fig. 2).

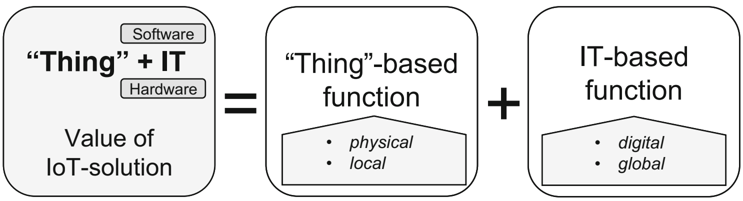

Fig. 2 The hybrid value of IoT solutions, adapted from (Fleisch et al. 2017, p. 8)

2.2 Value Creation, Value Drivers, and Value Capturing in Traditional Business Environments

Value creation is the heart of any business model and involves activities that increase the value of offerings either by encouraging the customer's willingness to pay for the offerings or by decreasing the opportunity costs of suppliers and partners (Hui 2014; Zott and Amit 2007). Value creation characterizes the form in which the firm's products and services are bundled to create value for a certain customer segment, i.e., creating the firm's product or services' preferability over a similar offering. The business model concept emphasizes the understanding of value creation as the total value generated for all business model stakeholders (i.e., investors, employees, suppliers, and customers). Therefore, the analysis of value creation must encompass not only the value added by a single firm but also the value bundle created by networks. Typically, value is created through a transaction, which can be described by three components: a transaction object (i.e., a physical product or service), an information stream, and a money stream. In traditional business models, the money stream is exclusively dependent on the prices of the product stream (Bucherer and Uckelmann 2011). Traditionally, the costs and prices of information are integrated into the product itself and do not create value independently.

Value drivers in a traditional business model context refer to the sources of value and the factors that enhance the overall value that a firm creates (Amit and Zott 2001). Amit and Zott (2001) introduced four key drivers for value creation in e-business: novelty, efficiency, complementarities, and lock-in. In an e-business context, novelty means that value is created by, for example, innovating the transaction structures and connecting previously unconnected parties. Efficiency is connected to transactions, in such a way that when the transaction efficiency increases, the costs per transaction decrease, and hence, more value is created. Complementarities mean that value increases by offering bundles of complementary products/services to customers, thereby increasing revenue. Lock-in means preventing the migration of customers/partners to competitors through, for example, digital bonus points, which creates value through the repetition of transactions (Amit and Zott 2001).

Value capturing describes the activities helping the monetization and revenue generation of the created customer value. While value creation focuses on increasing value, value capturing is about how the firm will appropriate some portion of that value for itself (Osterwalder and Pigneur 2005). Traditionally, in selling physical products, firms have focused on capturing value by transferring ownership through a sales transaction of perpetual ownership (Osterwalder and Pigneur 2005). For example, a classic revenue model for many product-oriented companies has been to research, develop, and produce a product that is then marketed in the form of a relatively fixed value proposition for a certain price to the appropriate customer segment. The one-time price paid by the customer for the product is practically the only source of revenue for the company, resulting in a so-called unit-based revenue scheme.

3 Value Creation, Value Drivers, and Value Capturing in an IoT Context

3.1 Potential Impacts of the IoT on Value Creation

The hybrid nature of the IoT construct plays a key role in how value is created in IoT environments. A valuable IoT solution is not just the sum of a physical "thing"-based function and a digital, connected IT-based function but also receives its value from an effective integration of each aspect. Although the "thing"-based function is an integral part of the overall value offering, it does not offer an increased value proposition compared to a "non-IoT thing" (without the addition of the IT-based function) (Fleisch et al. 2017). Therefore, the IT-based function of the hybrid construct appears to be the main value driver for value creation based on an IoT solution. Compared to traditional business models, the IoT helps to separate the IT-based function, and therefore the information stream, from the product and to shape it to become a value and revenue stream on its own. The separation of the information stream enables both the removal of geographical and physical constraints and the commercialization of the information in a virtual market. As a consequence, information represents a value in itself and its accessibility in an information marketplace represents one of the most important characteristics in the value creation process (Bohli et al. 2009; Höller and Karnouskos 2014).

Against this background, in an IoT context, it is important to understand the resource characteristics of information and information services that contribute to value creation. The value of information is nonexhaustive, increases with use, higher resolution (volume, accuracy, number of sources), and higher aggregation, and depends on the timeliness and personalization (Bohli et al. 2009; Bucherer and Uckelmann 2011). Accordingly, the value of information is highly dependent on a personalized actionable aggregation for a specific use case. Therefore, customization is a critical requirement for value creation (and value capturing) based on the information stream. Additionally, the importance of making information accessible and sharing it between information providers in a network becomes apparent (Bucherer and Uckelmann 2011).

The value of IoT applications is dependent on an effective integration of its features. Information is one of the enabling factors in this set. Fleisch (2010), Lee and Lee (2015), and Porter and Heppelmann (2014) identified key functions of IoT applications, driving value creation for customers. These functions can be grouped into three categories: trigger functions, security and validation functions, and customer feedback functions that influence the following capabilities: monitoring, control, optimization, and collaboration. The four capabilities must be considered cumulative. Each capability builds on the underlying functions and results of the preceding one. This ascending building of capabilities results in three modes of value creation facilitated by IoT: manufacturing, supporting, and value co-creation (Mejtoft 2011). The *manufacturing* mode adds value mainly by leveraging efficiency gains of connected things in the production and supply chain. The *supporting* mode is characterized by an increasing sensor density and therefore data density across a multitude of different industries and on different levels of the value network. A co-creative system between manufacturer and customer can be established. *Co-creatio*n represents the highest-level mode of IoT value creation. Whereas in a supporting mode, the IoT simply enabled co-creation between manufacturer and customer, in a co-creation mode, the IoT can now think for itself. Embedded intelligence enables the IoT itself to be the co-creation partner.

3.2 Potential Impacts of the IoT on Value Drivers

The four key drivers for value creation in e-business (Amit and Zott 2001) serve as a basis for identifying value drivers in an IoT context. To categorize value drivers in the IoT context, we rely on the factors of the independent information stream and value networks: customization and value co-creation. As a result, the following six categories for analysis are derived.

First, e*fficiency* represents a value driver in an IoT context, because efficiency comes along with reduced transaction costs that result from the reorganization of activities (Zott and Amit 2010). Given that the IoT can connect a huge number of different parties and span borders of firms and industries (Zott and Amit 2010), the amount of transaction costs plays a crucial role in the question whether activities have the potential to create value. The more efficient the activities are, the more likely they can contribute to firms' value creation.

Second, *network effects* represent a value driver in an IoT context (Bohli et al. 2009; Mejtoft 2011). Network effects are present when the value of a product, service, or technology depends on the number of its users. That is, the value of the entire network increases with the number of users in it (e.g., phones, Internet, social networks). However, to benefit from network effects, a critical mass of users is necessary; and a specific degree of the product or service's value is essential to ensure that other participants join and/or existing participants stay. Therefore, it is important to develop value offerings based on the IoT alongside the IT-based and thing-based functions (Mejtoft 2011). The mutual influence of both elements will be essential for reaching a critical mass and enabling investment in the platforms.

Third, *customization* represents a value driver in an IoT context. Customization offers a method for better differentiating value propositions directly by value, instead of prebundling a value proposition to cater to a market segment. In an IoT context, customizability often persists beyond the time of purchase, resulting in a prolonged value proposition, which can be developed further through IT-based upgrades (Hui 2014; Whitmore et al. 2015).

Fourth, many firms integrate services in their value propositions, a development called "*servitization*" (Kindström 2010). The reason for this integration is that product-based value offerings often come under pressure when commoditization of the market occurs due to increased competition and lower sales margins. The servitization of industries often requires firms to redesign their business models with a service orientation to create additional value. The topic of this so-called servitization and its effect on value creation is of particular interest in an IoT context because the hybrid nature of IoT value leads to always having a service part in the value chain because of the IT-based function, which is based on digital information (Fleisch et al. 2017). Service-based business models come along with a redefinition of the roles of the customer and other partners toward the roles of the co-creator and co-producers in the value creation process (Kindström 2010; Turber et al. 2014). Value for the customer is therefore created by having the ability to be integrated more closely with and earlier into the process of designing a customized value proposition. A problem of basing a large portion of the value proposition in service elements is that customers find it more difficult to appreciate the value of intangible services (Kindström 2010).

Fifth, *shared value drivers* are important in an IoT context. A distinctive feature of the IoT network is the interlinked and coherent nature of firm boundary spanning value delivery. This distinctive feature makes the individual motivations of a focal firm relevant to the entire network and thus creates shared motivations (Westerlund et al. 2014). Because all stakeholders in a network have incentives to increase the value of the platform, every stakeholder has an incentive to support shared value drivers, which are constituted throughout the entire value chain. That is, the value is heavily dependent on the compliance of all stakeholders in reaching a specified value characteristic.

Sixth, the *novelty* of business model elements itself represents an important value driver (Amit and Zott 2001; Zott and Amit 2010). Novelty acts as an amplifying and complementing force in combination with other value drivers. The value of novelty can be leveraged through the aspects of adopting new activities into the value proposition, finding new ways of linking these activities, or innovating the participants and their propositions in the value chain.

3.3 Value Capturing in the IoT

The IT-based function of the IoT also plays a key role for firms regarding value capturing. To identify how the IoT changes the ways of capturing value in this context, the focus lays on the revenue streams. Products become IoT-capable through sensors and connectivity and therefore enable manufacturers to generate additional value for the customer through IT-based functions (i.e., the independent information stream) via, for example, apps for remote control products such as heaters.

Given the independence of the information stream from the physical product, the IoT enables an additional value stream of information to be marketed and monetized independently from other value streams, resulting in completely new but also highly complex possibilities for value capturing. This monetized information stream results in new revenue streams even after the product is sold because software updates and fixes can refresh the value proposition, enable new features, or leverage functionalities for new use cases. This way of capturing value through an information stream is not possible in traditional business models and can extend the use case of a specific product, thus opening up the possibilities for prolonged and increased revenue streams.

At the same time, products of other manufacturers can profit from the generated information: for example, an electronic car maker will profit from data generated by a smart powermeter, which, in turn, profits from smart home data. The influence of a multisided market can result in new configurations of pricing schemes through, for example, ad-supported revenue streams or in exchange for usage data.

Furthermore, pricing schemes need to consider the distinct pricing mechanisms of the physical IoT product on the one hand and the information stream on the other hand, as well as a possible combination of the two. Pricing mechanisms, i.e., the determination of prices for the offered value, can be differentiated into two main groups: *fixed menu pricing* sets predefined prices based on static variables, while *dynamic pricing* sets prices based on market conditions (Osterwalder and Pigneur 2010). Features of IoT solutions enable new possibilities in both categories.

The increased capabilities for customization and co-creation make a virtually boundless variance of value proposition bundles possible. Pricing mechanisms can integrate "versioning" and "add-on" features, which are based, for example, on the resolution or timeliness of data streams (Bohli et al. 2009). Such versioning can also be applied dynamically to allow for a high degree of flexibility and therefore increased value for the customer. For instance, the customer can pay for the weekly aggregation of data but has the flexibility to request a higher granularity (e.g., daily aggregation) for an additional fee.

The addition of an independent value stream based on digital information leads to the possibility of basing revenue mechanisms on parameters other than those that were previously possible in traditional business models, namely, enabling an easier move from unit-based revenue schemes to value-based revenue schemes that are based directly on the value of service and information (Huber and Kaiser 2015; Kindström 2010). As an example, the traditional unit-based sale of cars can move toward selling the value of mobility in the form of revenue schemes based on runtime, distance traveled, or battery charging cycles and, in doing so, attract new customer segments. Another example is the move from per-unit sale of machines and bundled maintenance contracts in manufacturing toward value-based contracts based on, for example, uptime, output, or error rate.

Important factors in realizing such revenue schemes are the technical feasibility of measuring the value parameter and a transparent and clear proposition of the underlying value to the customer. Supplier and customer need to be in agreement on how value parameters are measured and used to determine the pricing (Kindström 2010). This necessity represents a challenge at a current point in time. While usage-based pricing would best leverage the value of information, often a subscription-based model is easier to implement and control by the supplier, because there is no need for metering the usage (Bohli et al. 2009; Bucherer and Uckelmann 2011). The predictable stream of recurring payments reduces revenue and cost volatilities for customers and suppliers alike, making suppliers reluctant to introduce new pricing schemes. The introduction of new pricing schemes is especially relevant because some possible models, such as product-as-a-service, significantly increase the buyer's power, as the buyers can switch between products much more easily in these models than they can with perpetual ownership (Porter and Heppelmann 2014). One possibility for mitigating this problem is to leverage value drivers such as customization and network effects.

It is important to emphasize that value can only be created and captured if the necessary data to build higher-level services are accessible. In turn, a higher value usually necessitates the input, storage, and analysis of more sensitive and higher resolution data (e.g., location and usage data). Accordingly, data providers demand increased compensation for higher value data. It will therefore become essential to transparently and explicitly show data providers how their data are used and what value they, in turn, receive and to incentivize them to continue providing these data (Porter and Heppelmann 2014). Firms need to gauge what data type and in what granularity and time sensitivity is required to deliver a certain value. In the next step, the question regards the degree to which the customer values these parameters and thus the degree to which the customer is willing to pay for the offering based on these parameters (Bohli et al. 2009; Leminen et al. 2015).

4 Discussion

This book chapter explores how the IoT can change the way value is created and captured and how value drivers are impacted by the IoT. Merging knowledge regarding the general characteristics of the IoT with insights on value creation, value drivers, and value capturing in traditional business environments, we demonstrate that the IoT is very likely to change value creation, value drivers, and value capturing in firms.

With regard to value creation, we suggest that the characteristics of IoT solutions (i.e., the independence of the information stream and its accessibility) result in new ways of creating value by commercializing the information stream in a virtual information network. The characteristics of IoT solutions also result in specific drivers for value creation in IoT environments: efficiency, network effects, customization, servitization and value co-creation, shared value drivers, and novelty. With regard to value capturing, we suggest that the new, independently marketed value stream of digital information allows for completely new ways of value capturing in the IoT context by creating new revenue streams for firms by switching from a unit-based revenue scheme to a value-based revenue scheme. This switch of the revenue scheme results in value capturing for the firm even after the physical product is sold.

Against this background, it appears to be obvious that the IoT leads to new business models. These new business models are based on a network-centric view of value creation and the independence of the information stream. That is, the importance of partner networks and creating value by integrating multiple products increases significantly. For the end customer, the value of an offering through the

IoT mainly depends on the degree to which it can be customized and integrated with an already diverse mix of products. Additionally, as customization requires the increased involvement of the customer as a co-creating entity, service orientation and intensified customer relationships gain major importance.

Our findings provide various theoretical and practical implications. From a theoretical perspective, we primarily contribute to the IoT research by focusing on the connected processes of value creation, value drivers, and value capturing. In this context, it is particularly noteworthy that we provide a better understanding of how value creation and value capturing are linked with regard to the specifics of IoT-based environments. For practitioners, first, our work might be valuable because we suggest that firms should assess their value propositions from a network-centric point of view. Instead of using an inside-out perspective and regarding other value offerings as competitors, firms should try to find common ground for generating value inside a network. Second, we suggest that firms should orientate their offerings toward the customization of products and the integration with already existing products owned by the customer. Again, this recommendation is in line with acknowledging the synergetic and complementary value of different solutions instead of following a closed-down, firm-centric bundle of offerings.

As with all research, our work suffers from some limitations. First, we relied on a conceptual approach to investigate value creation, value drivers, and value capturing in an IoT environment. Second, we did not focus on a specific business model framework as a unit of analysis. To address these limitations and to enlarge the interesting and important research field concerning value creation, value drivers, and value capturing in IoT contexts, we encourage future research to narrow down the scope of analysis to a specific industry or to focus on a specific part of the IoT architecture with the help of a specific business model framework (such as on the business model canvas) to gain more detailed findings. Simultaneously, we encourage researchers to conduct empirical research in the future. For example, researchers could perform case studies focusing on specific layers of the IoT or compare firms belonging to different industries in the IoT context.

In conclusion, IoT-specific characteristics shape the way in which value creation and value capturing can be achieved. We hope that this chapter encourages practitioners and researchers alike to consider the IoT from a management, strategy, and/or organizational perspective rather than solely focusing on the technical aspects of this important technology.

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