Navigating uncharted waters: Designing business models for virtual and augmented reality companies in the medical industry

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A B S T R A C T

New technologies are at the heart of industry transformation. Virtual and augmented reality companies provide fundamentally new ways of communication, treatment, education, and specialist training within the medical industry. However, business models for new ventures that target the medical industry have received scant attention within academic research. Using a multiple case study approach, we analyze how virtual and augmented reality firms create value for their customers in the medical industry. In all, we have studied eight companies that offer different types of solutions for their target segments. The results of the analysis are four design elements consisting of twelve positions and three design themes that define the similarities and differences between the business models for the companies. We contribute to existing research within the field by analyzing business models of the investigated companies using a design approach, classifying the virtual and augmented reality companies, and analyzing the role of new technology in the development of the medical industry.

1. Introduction

Virtual reality (VR) and augmented reality (AR) are two emerging technologies that have the potential to radically change markets and industries and transform the interaction among participants (Sherman and Craig, 2018); industries such as communication, entertainment, and education are under constant pressure to change owing to the new technologies (Ong and Nee, 2013; Lee, 2012). These technologies are already being used in medicine. According to previous research, VR/AR could be used for education, specialist training, assistance in diagnostics, teleconferencing, and patient rehabilitation (Kim et al., 2017; Iserson, 2018). Compared with other industries, medicine is considered one of the most conservative industries when it comes to the innovation and uptake of new technology (Stanton, 2012; Barlow, 2016; Shaikh and O'Connor, 2020). However, conservatism can be justified because of the high cost of new technology within the industry and the fact that professionals are dealing with people's lives. In turn, emerging technologies such as VR/AR could change traditional approaches and increase efficiency, thus reducing high costs. In the future, according to some current estimates, new technologies in medicine could change the fundamentals of the medical industry (Kipper and Rampolla, 2012; Attaran and Gunasekaran, 2019). It has been suggested that VR/AR might contribute to the democratization of medicine and support the development of necessary skills for physicians in a more efficient way (Kim et al., 2017). Furthermore, these technologies could

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accompany medical specialists from the start of their university education, so they could potentially be part of the daily practice of the specialist in the future.

Virtual reality is a computer-based technology that creates a new environment (Sherman and Craig, 2018). The main technical device related to VR is a display that isolates a user and offers new opportunities such as a specially created world that may simulate reality or be completely different from it. In turn, augmented reality is an interactive system consisting of a display, smartphone or tablet that combines digital and real objects (Bimber and Raskar, 2005). VR and AR have moved from technical innovations to part of everyday life in some industries. These technologies contribute to the development of new opportunities and new experiences in the interaction between companies and their customers (Radnejad and Vredenburg, 2019; Nussipova et al., 2019). VR/AR were first applied in the gaming industry and changed it substantially (Feijoo et al., 2012; Psotka, 2013). Now, companies in other sectors are also trying to use VR/AR technologies to improve the management of businesses, involve employees in business processes and increase the efficiency of operations (Rüßmann et al., 2015; Langley et al., 2016). Nevertheless, despite the partial success and diversity in the potential applications of VR/AR in medicine, our knowledge of VR/AR business models is very limited. Furthermore, previous studies on how to commercialize and promote VR/AR technologies in the medical industry provide few insights for entrepreneurs who target this market (Farshid et al., 2018; Wexelblat, 2014; Dodevska and Mihić, 2018). In addition, the bulk of the VR/AR literature suffers from a lack of coherent theoretical frameworks for analyzing the diversity of companies working with VR/AR.

Given this background, we decided to analyze companies that offer VR and AR solutions targeting the medical industry. The purpose of this paper, therefore, is to analyze the business models designed by VR and AR companies in order to capture value from their customers within the medical industry. To fulfill this purpose, we have used the activity system design framework developed by Zott and Amit (2010) and Amit and Zott (2012) to analyze the business models' key design elements and parameters. The business model design approach proposed by Amit and Zott (Amit and Zott, 2012; Zott and Amit, 2007) is a valuable framework for studying the formation and development of a company's business model. Amit and Zott offer this approach for the study of the organizational structure activities based on the relationship between the structural parameters of the company, its partners, ways of creation, delivery, and capture value. The key difference between the proposed approach and others (for example, Teece, 2010) are two sets of parameters that can be used by entrepreneurs to select and apply design elements and design themes. Business model design is suitable for studying new concepts, particularly their features in a lack of knowledge, for the novel phenomenon. This approach clarifies the difference between the new model and its analogues and reveals the features within the proposed model. Therefore, this approach provides a framework for researchers to analyze business models and propose ideas for their development.

We contribute to the development of the business model and the business model innovation theory through a systematic approach to the analysis of VR/AR of companies in medicine, identifying key unique and common blocks that form the companies' business models. We also offer a business model design contribution and demonstrate how companies can gain market advantage and increase their chances of success.

The rest of the paper is organized as follows. In the next section, we present the results from previous studies, concerning the four main areas in medicine in which VR/AR companies provide value for their customers. In section three, we describe the design framework that was used in this study and how the data were collected and analyzed. Section four contains the main empirical findings and consists of two parts: the observed design themes and the design elements. The fifth part of the paper is an analysis and discussion of the empirical findings, along with an implication section. The paper concludes with some limitations of the study and a number of suggestions for future research.

2. Previous studies on virtual and augmented reality in medicine

Interest in the development and role of applications of VR and AR technology in the medical industry has existed for several decades and is highlighted by a growing number of scientific publications devoted to this topic, as well as by the growing number of conferences and trade fairs (Riva, 2003; Gorini and Riva, 2008; Chirico et al., 2016). The overwhelming majority of articles that focus on VR/AR within the medical industry can be divided into four principal areas: the role of VR/AR in communication between the digital and the real worlds (Riva, 2003), the use of VR/AR in medical training and support (Pensieri and Pennacchini, 2014), clinical simulation using VR/AR (Ma et al., 2014), and how VR/AR can improve and make therapy more efficient (Kim et al., 2017; Iserson, 2018).

2.1. Communication

According to a study by Riva and Gamberini (2000), VR can be seen as a logical continuation of the already existing types of communication in medicine, more specifically, computer and telephone. The development of this type of communication could be implemented through the involvement of human sensory channels in the users' communication experience (Biocca and Levy, 2013; Vesselkov et al., 2018). The main development areas are within the progressive improvement of communication channels and graphics, the addition of offline characteristics to online objects, and the transfer of realistic experiences among participants in the process (Biocca et al., 2003; Lu et al., 2016). VR/AR are also important in facilitating the communication process between a patient and the physician, as well as for improving group therapy (Gorini et al., 2007; Riva et al., 2015).

According to several studies (cf. Schuemie et al., 2001; Riches et al., 2019), one of the key parameters of VR is a sense of presence. Participants of the interaction feel a sense of presence in a world that is outside the usual framework (Ijsselsteijn et al., 2001). Numerous studies have demonstrated the relationship between the level of presence and the emotions that arise from this perceived presence (Baños et al., 2008; Diemer et al., 2015).

Further development within the field of communication may lie in the development of Collaborative Virtual Environments, in particular, in supporting communication between groups of patients and physicians in person or through avatars. This kind of interaction promotes teamwork, learning and working with emotions (Cheng and Ye, 2010), and patient integration into society (Wallace et al., 2017). An avatar is an image of a virtual or augmented environment that is controlled by a person and displays its actions. In each case, a level of accuracy in reproducing actions is chosen by the economic and practical benefits (Kohler et al., 2009). Independent interactions of avatars with the surrounding virtual environment could occur due to contact with objects or other avatars, possibly leading to changes in the environment.

2.2. Training

VR and AR could also offer advanced opportunities for training and skills development for medical professionals (Gallagher and Cates, 2004; Gallagher, 2018). Immersion in the learning environment and the possibility of using new impressions for learning complements the study of anatomy (Codd and Choudhury, 2011), surgery (Thomsen et al., 2017), and ophthalmology (Le et al., 2011). New features could support traditional ways through new practical approaches in learning and practice (Yin, 2019). Nurses could gain knowledge in the use of new working methods with patients (Jenson and Forsyth, 2012). The use of VR/AR in combination with traditional training practices and webinars could gather a wider audience and play an important role in medical training (Kamel Boulos and Toth-Cohen, 2009).

Training also implies the use of AR capabilities where interactive actions are covered by the digital environment. For the student, the virtual and physical environments would overlap, creating a deep sense of presence and interaction (Barsom et al., 2016). AR could be adapted for different kinds of medical skills and could create a flexible learning environment, which is necessary for the training of high-quality specialists (Kamphuis et al., 2014). However, there are concerns that VR could completely or partially train specialists but allow little adoption of skills in a changing work environment (Wu et al., 2013).

2.3. Simulation

Since the 1990s, researchers have studied the use of VR/AR in the simulation of medical processes (Dinsmore et al., 1997; Marescaux et al., 1998). Advanced computing technologies make it possible to prepare and process large amounts of information that allow the simulation of an exact replica of the patient (Pensieri and Pennacchini, 2016). The increase in computational capacity reduces the need for supercomputers to integrate massive databases based on the visualization of damaged organs, which in turn allows surgeons to practice an upcoming operation in a virtual environment before implementing it on the patient.

The most promising area in medical VR/AR is surgical procedures. For example, previous studies have demonstrated that the virtual environment has a significant effect when it comes to reducing the length of the procedure and improving accuracy when comparing the results of surgeons who have passed and those who have not passed the simulation training respectively (Gurusamy et al., 2008; Vaughan et al., 2016). Other studies have noted a reduction in the number of actions taken by the surgeon during the procedure and have therefore recommended that the VR or AR training should be included in the standard training programs for surgeons at universities (Grantcharov et al., 2004; Barsom et al., 2016). Many researchers have highlighted the importance of integrating VR simulation into the training curricula of surgeons. However, studies have emphasized the importance of interval training (Gallagher et al., 2005), the need for a combination of planning and simulation to increase efficiency (Slater and Sanchez-Vives, 2016), and the difficulty in reproducing the exact tactile sensations of surgeons (Pelargos et al., 2017). In addition to the capabilities and limitations of the VR, medical professionals could benefit from implementing AR, such as receiving feedback when using real equipment and materials (Botden and Jakimowicz, 2009; Barsom et al., 2016). Moreover, AR simulators allow for an increase in the students' levels of performance assessments (Pensieri and Pennacchini, 2014). This type of simulation allows for the use of a hybrid environment, that is, to get a tactile connection with the subject and feedback from real objects.

2.4. Therapy

Psychologists and psychotherapists alike have used the advantages of VR/AR to change the principles of interaction between a patient and a computer. An individual becomes not only an observer of information on the screen but also an active participant in their interactions in the new virtual world (Cherniack, 2011; Levac et al., 2015; Zhou et al., 2018). Patients could receive recommendations for recovery (Merians et al., 2002; Tashjian et al., 2017) or disease prevention (Wilhoit et al., 2017). Numerous VR applications contribute to overcoming different types of phobias or fears, like the fears of flying (Czerniak et al., 2016), public speaking (North et al., 2015), or spiders (Morina et al., 2015).

The use of VR in psychotherapy is based on images and emotional responses that are equal to those from reality (Riva, 2005; Metcalf et al., 2018). According to previous research, the difference between reality and computer reality has been reduced over time (Glantz et al., 1997; North and North, 2016). Moreover, VR contributes to the ability to feel and endure life trials in a different way (Baños et al., 1999; Serrano et al., 2016). Involving the feelings of the patient in the rehabilitation process allows for the transformation of the results compared to those of the patient's own fantasies. In turn, this may increase efficiency and reduce costs of the staff and the number of required visits (Gerardi et al., 2008; Maples-Keller et al., 2017). Despite numerous validations of the effectiveness of VR in treating disorders (Rothbaum et al., 2000; Garcia-Palacios et al., 2002; Beidel and Frueh, 2018), there are certain restrictions when it comes to the use of the technology. Pensieri and Pennacchini (2014) highlight two: the unwillingness of the patient to repeat events and the physician's inability to control the process.

VR/AR could also simulate situations in which children with autism could obtain the necessary life skills and increase the likelihood of using them in reality (Parsons and Mitchell, 2002). Studies have also shown the effectiveness of using a virtual environment with children to improve their social interactions and help them understand and internalize the rules of behavior in the social sphere (Herrera et al., 2008). Researchers have also highlighted the capacity of using VR to support patients who have lost a limb (Henderson et al., 2007). Virtual limbs can contribute to the total perception of the subject in terms of image and touch. There have also been successful experiences supporting people with a distorted body image (Mölbert et al., 2018) and obesity (Manzoni et al., 2016).

These studies demonstrate the potential of VR/AR technologies for different types of medical purposes. However, there is still a significant research gap regarding the application of focal technologies from the point of view of commercialization and business development. In addition, an analysis of the characteristics of companies that develop VR/AR products and services in the medical industry has not been performed. We aim to fill this gap using a detailed analysis of the business models of firms that are specialized in the development and application of VR/AR technologies in the medical industry.

2.5. Business model for VR/AR companies

The use of VR/AR technologies is gradually increasing in various industries. Business models for the companies offering such solutions are aimed mainly at providing new experiences for their customers (Flavián et al., 2019; Hudson et al., 2019). For example, companies operating in the tourism industry offer their customers an impression of the interaction of real objects with a virtual layer (Callejas Cuervo et al., 2011). Users of the service can access information and interact with city sights in a new format. In turn, the company creates revenue by promoting restaurants and shops for tourists. González (2015) describes a VR/AR solution that offers historical information for tourists. This app can decrease the demand for professional guides. The business model for such a company is oriented towards the younger generation, who also prefer technological solutions while traveling. According to Morrison et al. (2011), navigation solutions are more intuitive for users than paper and digital maps, and they offer additional information and service in a convenient form.

VR/AR companies successfully operate in the educational industry, offering solutions for school and university audiences (Kavanagh et al., 2017; Makransky and Lilleholt, 2018). First, the assimilation of new knowledge increases with the use of new technologies. Students more easily combine theoretical and practical knowledge. Second, users get acquainted with the new technology to a certain extent, and they become more loyal to it in the future. The business model for the educational VR/AR companies is aimed at audiences who are most receptive to new technologies, it intends to solve social problems, and it is environmentally sustainable (López, 2020; Liu et al., 2017).

Piroozfar et al. (2017) and Ahmed (2018) explore the business opportunities of VR/AR in the construction industry. VR/AR solutions in this industry are based on the advanced development of professional skills in graphics processing, architecture, planning, and construction. The unique value proposition of these companies differs from the classic ones in interactivity and collaboration capabilities. It is also worth noting the research on business applications in healthcare (for example, Huang et al., 2018). The business model for healthcare companies can be based on the collaboration with opinion leaders and specific knowledge in the field. Cooperation with opinion leaders contributes to the successful development, promotion and sales that an IT company often lacks (Kulkov et al., 2020). A business model based on getting additional information during interactions with other readers is suggested by the media industry (Greengard, 2019). The newspaper reader gets access to voice and video comments from professionals or other subscribers. The customer can track the development of the discussion over time or can get extra information from a related field. Other media companies may offer AR links to information repositories (Rauschnabel, 2018).
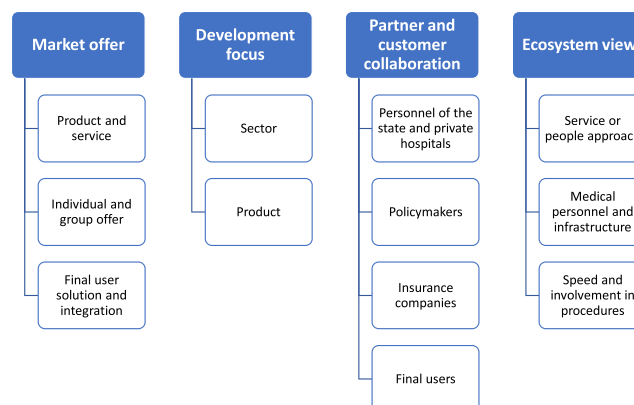

Fig. 1. Four unique design elements and twelve design positions.

The use of VR/AR possibilities transforms the traditional relationship between producer, seller, and customer. This chain is filled with new knowledge and experience. VR/AR service is gradually transforming from an additional service into a new way of communication and is replacing traditional, one-side communication with a powerful communication environment (Hammick and Lee, 2014; Wen and Gheisari, 2020). Customers devote more time to the VR/AR resource, due not only to the novelty but also to the new opportunities that were previously unavailable. In turn, the main common limitation of articles on the business application of VR/AR is the lack of a systematic approach to studying business models and processes and the use of a single study for research. Researchers offer case studies of successful AR/VR integrations but provide little sufficient knowledge for the following companies (Duane and Hagl, 2018; Ibarra et al., 2018; Mihardjo and Alamsjah, 2018).

3. Research design and method

Accounting for the lack of research on business models for companies involved in the development of medical VR/AR applications, which is an emerging and therefore understudied phenomenon, a multiple case study was chosen as a research strategy (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). In this study, we have used the business model design approach to investigate the formation and operation of VR/AR companies in an uncertain environment (Zott and Amit, 2010; Amit and Zott, 2012). This approach allows for the evaluation of the activities system of the company, its partners, and customers, and for the assessment of mutual influence and the creation of shared value (Pauwels et al., 2016). The business model design approach entails using two sets of design parameters to analyze activities: design elements and design themes. Design elements are used to shape the activity of the system and distinguish it from other systems. Fig. 1 shows the content of design elements in our case.

In turn, design themes are used to define common themes that form shared elements in the model under consideration and classify models of activity systems (Amit and Zott, 2012).

The perspective of developing a new system of activities is particularly relevant when studying a new type of activity or using new technologies to change traditional relationships, as it offers new tools for identifying and studying new elements and connections. Firstly, this approach allows for the identification of new opportunities and enterprise models. Secondly, it allows for the identification of the heterogeneity of the environment, new themes, and new business models. Thus, the resulted designed framework will allow for the exploration of the proposed structure, the use of new technology, and its impact on its partners of the company.

Our sample consisted of AR/VR companies that only focus on the medical market. Based on Riva (2003) and Pensieri and Pennacchini (2014), we have identified four areas for the use of VR/AR in the medical industry: communication, training, simulation, and therapy. Using these criteria, we have identified a sample of 42 companies that meet the necessary requirements. We have decided to limit our research to those companies that already offer a product to the market, excluding those that are at the stages of prototyping or development. We argue that focusing on companies with products that are already being applied in the industry gives us a greater understanding of the technology and its capabilities and facilitates the assessment of the necessary parameters of the business models of the companies. Among the ten companies in our final sample, representatives from eight of those companies agreed to take part in this research project. Table 1 presents the final list of companies that participated in the study and their main characteristics.

For each case, we prepared individual company histories using open data that were available. After that, we contacted potential interviewees at the focal companies. To increase the likelihood of a positive response, we attached prepared cases of companies and explained why it was important for us to obtain data from the focal company (Yin, 2017). During the interview with the respondents, and later through email, it was possible to validate the initially collected information.

As the main source of information in this study, we used interviews with the CEOs and project managers of the VR/AR companies. The semi-structured interviews were made during the first half of 2019 using the general interview approach (Creswell and Poth, 2017). This approach is designed to collect the same general information from all interviewees, giving a certain degree of freedom and adaptability in obtaining information. Key topics and questions from the interviews were discussed in meetings in the research group. The individual interviews lasted 30–80 min and were conducted in English and transcribed verbatim.

For a better understanding of the social structure of the context, additional sources of information were used. In our case, the information was gathered from industry reports, web pages of the studied companies and other VR/AR companies, presentations of the companies, and industry and trade associations. This information contributed to the development of each focal case and to the validation of data obtained during the interviews (Flick, 2004).

We used NVivo Pro 12 software to analyze the text material after the transcription of the audio interview. Each of the researchers conducted an independent analysis and presented results to the group. The summarized results were offered for evaluation to the

Table 1
List of companies participating in the study.

	Name of company	Acronym	Application area	Country of origin	Type of reality	Respondent
1	Delta Cygni Labs	DCL	Communication	Finland	AR	Executive
2	XMReality AB (publ)	XMR	Communication	Sweden	AR	Key Account Manager
3	Byon8	B8	Training	Sweden	VR	Project Manager
4	Herosight	HS	Training	Sweden	AR	CEO
5	Surgery Vision	SV	Simulation	Finland	VR	CEO
6	Alteruna	AL	Simulation and training	Sweden	VR	CEO
7	Adesante Therapies	AT	Therapy	Finland	VR	CEO
8	Peili Vision	PV	Therapy	Finland	VR	CEO

representatives of the interviewed companies. The opinions of the company representatives played a key role in the selection of the final parameters for the design of elements, positions, and themes.

The analysis of the data was made using cross-case analysis (Eisenhardt, 1989). Cross-case analysis is a typical way of identifying common patterns and differences across multiple case studies (Eisenhardt and Graebner, 2007). Typically, cross-case analysis is the second stage in analyzing the collected data and is a way of aggregating and summarizing information. Researchers use cross-case analysis to identify specific general results from their sample. For this analysis, we selected the categories and measurements that we used to identify differences and similarities in the focal cases (Miles et al., 1994). The categories and measurements were determined by the elements that surfaced during the interviews and were repeated in all cases (Yin, 2017). After the initial research, we identified nine design elements that included twenty-two positions. After a deep analysis of the interviews, we formed four design elements that were validated by the respondents. The design themes were formed after analyzing and matching the cases with each other. After that, we compared the data and identified the links that unite the companies in the design themes. As a result, we formed groups of two to four companies that matched each of the themes. The results were proposed and approved by the respondents from the companies. In the deep analysis of the cases, two additional researchers who did not participate in the interviews were involved. Using this strategy, the validity and reliability of the results were enhanced (Lincoln and Guba, 1986).

The design elements were identified during the analysis of the interviews and were not predetermined. Moreover, identifying design elements, design positions, theme design, and subsequent data analysis was a key task of the study. Therefore, all design components were completely inductive. In turn, quotes from the interviews became the basis which formed the design positions, followed by the design elements and design themes (see Appendix).

4. Empirical findings

In this section, we present the empirical findings from the cross-case analysis of the companies. In all, we identified four design elements and three design themes during the interviews with the respondents using secondary data.

4.1. Design elements

The design elements are the key parameters that constitute the business framework of the company (Zott and Amit, 2010; Pauwels et al., 2016). We have identified four design elements after conducting interviews with respondents from the eight companies, which has led to the creation of twelve positions validated by the respondents. These positions formed the four design elements. Table 2 demonstrates the final positions and how they form the design elements. In turn, Table A1 (Appendix A) presents some key quotes that support our analysis.

4.1.1. Market offer

The market offer consists of the services and/or products that the focal companies offer to the market. The proposed offer can replace traditional methods within the medical system, offer a new way of solving existing problems, and even develop new markets. The final users, represented by physicians and students, can gain access to software for education or the training of special competencies. In turn, the marketing effort directed towards the B2C market is limited by the lack of hardware devices for the final users. Moreover, new methods of treatment, as well as a lack of regulation among insurance companies, cause physicians to become wary.

Most of the proposals are developed as a specialized solution for existing problems on the market or the needs of a particular customer. However, the developers emphasize that the adaptation of the offer to the medical industry requires few resources. Thus, an individual offer becomes one element of a group offer that creates additional value for the customer.

The majority of the studied companies consider hospitals, both public and private, to be the most attractive partner for their businesses. However, companies distinguish between two different approaches in sales. The first approach is selling the service to the hospital, to be used for the hospital's own needs or for the patients. The other approach is to be a subcontractor, or part of a large system that is sold to a hospital and to provide specific support in their area of expertise. In this case, the respondents tend to focus more on product development and cost reduction.

4.1.2. Development focus

The next design element is the development focus, which refers to the strategic focus on development relative to a sector or product.

Table 2
Four design elements consisting of twelve positions for VR/AR companies from the medical industry.

Design elements	Market offer	Development focus	Partner and customer collaboration	Ecosystem view
Positions	Product and service	Sector	Personnel of the state and private hospitals	Service or people approach
	Individual and group offer	Product	Policymakers	Medical personnel and infrastructure
	Final user solution and integration		Insurance companies	Speed and involvement in procedures
			Final users	

The sector's choice to develop and offer and the possibility of developing a brand determines the company's position in the relevant market. The offer of an adapted solution in a new market tends to raise concerns on the part of new customers. Acceptable solutions in engineering or communication are less applicable in the medical industry. In turn, attempts to use the same brand in various industries could affect the possibility of acquiring new customers from the medical industry.

The focus of product development can be viewed as the creation of an offer for a particular medical niche or an expansion to other medical needs. For example, Peili specializes in rehabilitation. In turn, in addition to simulation, Surgery Vision also develops the therapeutic direction under the brand Adesante Therapies. However, in general, companies with a medical focus are more specialized in medical applications.

4.1.3. Partner and customer collaboration

The majority of the companies in this study indicated that the staff of private and public clinics are the most important target segment. In both types of clinics, on-site demonstration of equipment for physicians, nurses, and sometimes administration are conducted. Depending on the type of application, there might be an agreement for testing, offering several sets of equipment to the hospital, or even inviting hospital staff to visit the developer for trial tests and to develop the individual offer. In turn, further cooperation requires relatively little remote support from the developer when it comes to communication and therapy cases, but as mentioned, a tighter cooperation is required for training and simulation.

Cooperation with policymakers is necessary for the development of a new market. For example, Peili offers a rehabilitation service for neurological patients that was not previously available on the market. Collaboration in the development and testing of new products and services with major regional hospitals are important to get the necessary references and possibly joint publications in specialized medical journals. The collaboration is also important for the integration of a new solution on the market. The approval process by policymakers for new solutions is also relevant when working with insurance companies. Including a new solution in the list of existing solutions offered by insurance companies requires an individual approach in each case; however, the respondents emphasized that the process was not very complex but time-consuming.

Companies with a specialization in communication, training, and therapy highlighted the desire to start working with the final users and form a platform for their needs. A final user could use its own hardware set with remote access to the necessary software, thereby reducing the need to involve additional staff. For example, patients could communicate with physicians and reduce the need to visit medical facilities, physicians could maintain and develop professional skills remotely without visiting the prepared premises, and therapy could be provided remotely in conditions that are more comfortable for the patient.

4.1.4. Ecosystem view

One of the topics that often arose during the interviews was the role of new opportunities to change the medical industry. VR/AR companies offer value by increasing the importance of their service solution, thereby reducing the need for additional staff and facilities. In the majority of cases, hospitals suffer from a lack of staff and a very high workload among their personnel. Hiring additional staff may not be possible due to a lack of funding, a lack of specialists in the market, or an unattractive workplace. In the short- and mid-term, VR/AR companies seek to reduce the need for extra staff and minimize peak workloads. However, some VR/AR companies have solutions that would reduce the need for medical personnel in the industry and replace the procedures performed by people with software services in the future. As a result, the need for a specialized infrastructure such as training rooms and communication places is decreasing, and the use of the patient's own apartment for therapy or training is increasing. Nowadays, hospitals are forced to create additional infrastructure or to use outsourcing for services where VR/AR could be implemented. However, new technologies and solutions support the provision of medical services.

In addition to the new type of cooperation implied by the solutions, VR/AR opportunities suggest an increase in the speed and involvement of cooperation among the participants. For example, the greater integration of a patient with a stroke into the treatment

Table 3
Design themes in the study.

Design themes	Changing the rules within the medical industry	Creation of the new niche in the medical industry	Adaptation to the non-medical industry
Market offer	The transition from the physician-patient principle to physicians-patients	Formation of a new medical service or a new approach to treatment	Solutions for similar issues with minimum product changes
Development focus	State hospitals, policymakers	Private hospitals, patients	Decision-makers
Partner and customer collaboration	Change in cash flows in the B2B market	The transition from B2B to B2C market	Complementary services
Ecosystem view	The role of the service increases, the need for personnel decreases or the structure of personnel changes	The role of the service increases, the need for personnel decreases	Primary factors: response time and quality of service / Secondary factor: Cost reduction
Cases	Alteruna, Herosight, Surgery Vision, Byon8	Peili Vision, Adesante Therapies	XMReality AB (publ), Delta Cygni Labs
Representative quotes	"When Apple introduces its glasses, it will be a paradigm shift in the industry." (HS) "There is no question about them starting to use the software because it helps. […] Every failure matter." (SV)	"We form the market and enable people to live a quality life." (PV)	"It is not a future, we have it today." (XMR) "The challenge is not the technology but about mindset, a new way to work." (XMR)

process proposed by Peili may facilitate a speedy recovery regardless of age. In the case of Alteruna, users note that the speed of skills acquisition is far higher compared to a standard learning process based on observing colleagues that are more experienced. Surgery Vision customers indicate that, when early, previously unavailable information becomes open; it increases the success of the procedure and reduces the need for repeated procedures.

4.2. Design themes

The findings in the interviews also demonstrate that medical VR and AR companies differ in their structure depending on what approach they have in regard to the design elements. In the next part, we offer the following set of parameters that characterize the design themes of medical VR and AR companies. The design theme unifies the specific type of company and its various design elements. The design themes for the VR/AR companies were identified during the interviews and later analyzed using cross-case analysis. We have identified three specific design themes to describe the types of VR and AR companies in the study. Table 3 illustrates the different types of VR and AR companies in the study, their differences and similarities with respect to the four design elements, and the position of companies given in this structure.

4.2.1. Changing the rules within the medical industry

Companies that offer new solutions for the existing market have to face a number of issues, including lack of trust and lack of previous recommendations, sometimes described as the liability of newness. Moreover, the medical industry is often claimed to be one of the most conservative industries there is. Most often, the decision to use a new product or service goes through a multi-stage agreement and on-site testing before being put to use. Simultaneously, the regulatory authorities analyze and test the products and services for a very demanding market. The developers of VR/AR solutions strive to carefully select hospitals and personnel for cooperation, as references may not be sufficient to obtain new customers on the local market and abroad. Such companies choose large regional state hospitals or university hospitals with a large number of patients and leading experts in the field. However, such cooperation causes certain limitations, for example, the speed of interaction with personnel and competition from other projects in which personnel are involved. In turn, physicians may consider the problem as insignificant or the value of the project as insufficient.

VR/AR technologies also contribute to changes in interaction between participants of the medical industry. First, it concerns the ability to conduct parallel processes. For example, more students or doctors can be trained at the same time; physicians can work with a large number of patients. Second, previously unavailable simulation technologies allow for collaboration and cooperation among physicians. The main task in changing the rules within the medical industry case is the cost reduction of training specialists and the time it takes to rehabilitate patients. In doing so, VR/AR companies contribute to increased efficiency in using already available resources for medical purposes. For example, cash flow from hiring temporary staff may be redirected to other types of necessary services. In changing the rules within the medical industry, VR/AR services are complementary to personnel that had previously been involved in the provision of medical services.

4.2.2. Creation of new niches in the medical industry

The creation of new niches in the existing market or developing fundamentally new markets is regularly associated with business model innovations. However, business model innovations in the rather conservative medical market require additional efforts. The main objective for companies when creating new niches in the medical industry is to significantly change the approach to problem-solving or developing a new service that has not previously been provided to the customers. For example, Peili Vision has implemented a cardinally new approach to specialized recovery, whereas the patient previously could rely more on their personal abilities.

Companies developing new niches are more likely to target private medical clinics, where the decision could be made solely by the owner or a top manager. Long and complex negotiations and co-operative efforts with public hospitals could be problematic for a start-up with limited resources and time. However, collaboration with physicians at public clinics could be more promising, as they could be involved as consultants or opinion leaders within a particular field. Shifting the initial focus from the B2B market to the B2C market is also associated with difficulties in working with public institutions. However, companies working in the focal format confirm their intent to work with public hospitals in the future.

The development of a new service or fundamentally new approach in problem solving forms the relationship between market participants. For example, the traditional teaching of medical students can be replaced by a new approach to teaching and learning, as in the Byon8 case. Such a transition cannot simply be called a change in the rules of learning since a fundamentally new, previously unavailable approach is being formed.

4.2.3. Adaptation to the non-medical industry

It is possible for the medical industry to adopt some solutions that have been developed for other markets. However, gaining the trust of new customers could become an issue for the companies trying this transfer of solutions. In general, physicians are skeptical about adapting applications from other industries to treat patients, but they are positive about new products that facilitate additional services, such as communication. XMReality AB (publ) originally developed its communication solution for mine clearance and other military purposes; Delta Cygni Labs developed its own solution for the maintenance of the International Space Station. The kinds of references they have received from primarily public partners may have a positive impact on the acquisition of new customers, but they are the exception. The majority of VR/AR developers acknowledge the issues with medical market collaborations if it is non-prioritized for them. As exceptions, cases with insignificant product changes, such as communication, or cases that provide a platform-based solution for different purposes, such as training, could transition to the medical industry. These typically offer complementary

services that reduce costs, time, or other relevant problems faced by medical companies. VR/AR developers appeal to the decision-makers in a particular field or company. However, the medical references offer few advantages for obtaining customers outside the medical industry.

The proposed findings suggest that the design themes are determined by the goals of the VR/AR companies (changing the rules, creation of a new niche, and adaptation). These goals represent a general theme that accompanies the company and associates with various design elements.

5. Analysis and contribution for theory and practice

This study explores the role of VR and AR in the medical industry by describing the business models of companies and identifying their key parameters of similarities and differences. Previous studies have been limited in the knowledge and theoretical methods for determining and analyzing various business models for VR and AR companies operating in the medical industry. The purpose of our research is to increase our understanding in these areas and start to develop a theory of business model innovation among those companies.

As a result of the study, we propose two main contributions to the business model and business model innovation literature and several additional ones to the theory. First, the results of our study demonstrate that companies engaged in the development of medical VR/AR applications use different business models, generally determined by their product or services. The majority of companies started by selling services to large public hospitals at the early stages of development, but they were later forced to adapt their proposals depending on the innovativeness of their ideas. In addition to attempts to change the traditional procedures in the medical industry, companies can develop new niches that meet customer needs, which have been acknowledged by previous research (Ma et al., 2014; Rojas et al., 2016). This finding highlights the importance of defining and applying design parameters for developing business models of companies working on developing VR/AR applications, thereby contributing to the development of business model design theory. Some previous studies are consistent with our results and allow the use of business models from other industries (Ong and Nee, 2013; Le et al., 2015; Kim et al., 2016; Jung and tom Dieck, 2017). However, the results of our study highlight some additional parameters that are of great importance in the medical field, for example, the parallel assessment and control of the product by not only the customer but also various policymakers, regulatory bodies, and other significant players in the market.

Second, the challenges of facing customers or final users influence the development of an application, we emphasize the importance of other actors in developing products and services. We demonstrate that medical VR/AR companies could differ in four key parameters (market offer, development focus, partner and customer collaboration, and ecosystem view). By identifying different types of medical VR and AR companies, we contribute to the research in assessing the characteristics of the focal companies and industry (Guo et al., 2019; Frank et al., 2019). Despite the apparent homogeneity of the medical industry, we have identified several types of strategies for companies that can be applied to the medical market or adapted in the transition (Sabri et al., 2018).

Our proposed design aspect of business models for VR/AR companies complements a few studies in various industries from a more theoretical point of view (Dunleavy and Dede, 2014; Dunleavy, 2014; Yin, 2019). We offer the design perspective based on the activity framework, stressing design themes as parameters for studying the development of business models for the focal companies. The design approach involves determining the key blocks that form business models and classify companies. Companies are distributed according to the identified design themes, depending on the novelty of their product for the market. The design approach allows researchers to continue research, develop additional assumptions, and test other available theories.

Our study coincides with numerous studies that focus on the transition of services from offline to online (Mills and Plangger, 2015; Schwab, 2017). Traditional medical procedures, visits to physicians, and training and preparation for different types of medical procedures can be supplemented or completely replaced by new solutions. At the initial stage, this allows for the reduction of costs, increased efficiency, and concentration on the core businesses. However, staff reductions could cause other types of complications, such as reduced employee motivation. Simultaneously, not all final users can or want to adapt to new technologies and may prefer traditional methods. Additional opportunities to use new technologies, such as flexibility, the reduction of procedure time, and new opportunities for communication can have a positive impact on the integration (Radnejad and Vredenburg, 2019). Finally, when it comes to innovations, the conservatism of the medical industry can be one of the limiting factors for integrating new solutions (Niemelä et al., 2019; Shaikh and O'Connor, 2020). Therefore, this parameter must be taken into account by companies that plan to focus on this market (Snihur et al., 2018).

Our research also offers two key practical contributions and several additional ones for industry participants.

First, we declare that AR/VR solution providers should choose a strategy for business development in the medical industry, taking the innovativeness of the solution into account. If a company offers a disruptive solution that did not previously exist on the market, the private clinics and other organizations that are independent of public funding should be oriented (Skica et al., 2019). Moreover, the support of physicians from private clinics may assist in the B2C segment. Companies should demonstrate efficiency in working with public hospitals and insurance companies. We would like to recommend cooperation with universities and research laboratories to collect the necessary evidence and change the attitude toward a new solution (Bazan, 2019). When changing the rules, VR/AR companies should start collaborating with public hospitals. We draw attention to the importance of choosing a pilot project. The greater the importance of the hospital in the region, the more value it adds to the project. Cooperation with a chief metropolitan hospital is advantageous in the product development, and it has a certain value for the export of services. However, such cooperation may also have disadvantages, for example, an increased waiting time for a response from partners, the workload of physicians, and more competition from other projects. We recommend that non-medical companies consider the medical industry as a project that differs from other areas. The experience gained from non-medical industries could hardly be relevant for the medical industry, as it offers little value to medical customers. Customers may also doubt the new solution if it was previously developed for another industry.

Second, we insist that the approach to product distribution is important for companies that offer VR/AR solutions for the medical industry. We demonstrate that direct sales and sales through large medical integrators or consultants could be considered in different cases. In general, the principle of direct sales for private and public clinics coincide. The solution should be offered through hospital management, and physicians should participate in local adaptation. Hospitals are interested in trial periods and testing capabilities. In turn, collaboration with large integrators or consultants leads to the loss of a company's own brand, and the focus is on product development rather than marketing. The AR/VR solution can be integrated by default for implementation in standard medical procedures. This approach could provide rapid growth, however, and the required reputation could be difficult for start-ups.

We also pay attention to a different approach in the organization of after-sales support depending on the company's specialization. Communication and therapy solutions require fewer support resources than training and simulation. In the case of communication, users just change the communication software; in therapy, a nurse or relatives can provide assistance for the patient. Training and simulation solutions require more support, as this is related to a physician's professional activities or training.

The strategy for entering the medical market for the VR/AR company should be based on the key partners, which are hospitals and specialized professionals. Effective management of these relationships is the most valuable resource that companies have. In the majority of cases, having a technology or a patent is not enough to enter and grow in the market. IT companies do not have the necessary medical expertise, access to patients and treatment information, and status in the professional medical community. Business model innovation for the focal companies is based on interactions with opinion leaders and the largest regional clinics or private clinics who are ready to try new approaches in their practice and are not bound by a complex hierarchy and other barriers.

The positioning strategy of the VR/AR company is closely related to the novelty of the proposed solution. Design themes respond in different ways to the novelty of solutions for the medical market: minor changes in usual practice, significant changes, and the transition from personal interaction between parties to general interaction of many with many. However, in all cases, the use of a new solution is increasing at the expense of convenience, cost reduction, or novelty. Moreover, the transition from the classic medical B2B market to the B2C market is not typical for medicine. Companies may not choose a strategy for entering a complex market through overcoming multiple industrial barriers but by turning to the end user of the service or its representatives. The success of such companies and the validity of this approach should be clarified in further research.

We point out that the main limitation for B2C development is the insignificant prevalence of hardware components. Cost reduction of such devices, increased availability, and entry of an IT giant leader, for example, Apple on the AR/VR market, will contribute to the promotion of the technology.

The identified design elements and themes could be used by nascent entrepreneurs to determine the potential market, develop their business model, and devise a strategy for the future. Business incubators and accelerators could use the proposed design elements and themes to support entrepreneurs working with VR and AR applications. We also see the opportunity for business advisors to have a practical tool for targeting start-up founders. Other actors in the business ecosystem, such as associations of VR/AR developers, can use this data to demonstrate the potential for entering the medical market and suggest practical steps to increase the likelihood of success for the companies.

The existing literature offers a single case study of various VR/AR applications in many industries. In turn, we offer a systematic approach to studying the business models of VR/AR companies in the medical industry. We demonstrate how companies create value for their customers and promote solutions in the market. We demonstrate the differences between companies and their unique business models, as well as how companies are similar to each other. Moreover, we make recommendations for new companies who are targeting the medical market. To our best knowledge, this is the first systematic study of VR/AR business models for companies operating in the medical market.

6. Limitations and further research suggestions

There are some inherent limitations in our study that could be mitigated in future research. The results are based on a relatively small number of VR/AR companies and applications that agreed to participate in this study. However, we acknowledge the fact that the proposed companies may not represent all possibilities within the field. Further research may also find areas in other industries that are applicable to the medical industry. Our research can therefore be viewed as a starting point for studying changes in the business models of companies operating in the focal area. Studying and comparing companies from different design themes may contribute to the development of certain patterns that can be used by the next generation of entrepreneurs and researchers. Companies with different design themes can transform medicine using different approaches. Assessing an impact and identifying parameters could become an important step toward understanding the transformation of the medical industry. Factors that influence the adaptation and use of new VR/AR services are not covered in the present study. However, the improvement of such parameters could contribute to making fewer mistakes at different stages of the product development.

7. Conclusion

New technologies have the potential to significantly change traditional markets as well as how participants interact. The article explores the previously uncovered analysis of virtual and augmented reality companies offering solutions to the medical industry. We propose four unique design elements consisting of twelve positions and three common design themes that systematize the business models of the case companies. The main contribution of the research is the development of business model and business model innovation theory and the application of the theory to the medical industry. Moreover, we offer a number of steps that can be applied by nascent technology entrepreneurs to enter the medical market or to develop companies within it.

Appendix A

Table A1
Data and quotes that formed design elements for the study.

Design elements	Constructs	Quotes
Market offer	Product and service	"[A potential customer] asked if I could combine haptic robotics and VR for the surgery application." (AL)
		"People would like to help their parents and grandparents with a remote control." (DCL)
		"[A solution] does not limit you in the amount of therapy." (PV)
		"Training is more flexible and accessible." (HS)
		"We train students in VR." (B8)
		"3D service instead of [MRT] slices." (SV)
	Individual and/or group offer	"The platform could be used both for individuals and groups." (AL)
		"In the maritime industry, we concentrate on individual offers. […] Medicine provides us opportunities to work with numerous clients with similar tasks." (DCL)
		"It is always possible to make individual exercises but we offer packages for patients. […] If we make a new exercise, we share it with other users." (PV)
		"Requirements for courses and case studies at different universities are very similar. A new case can be available immediately to all customers." (B8)
		"We grow with our customers […] starting with country offices and then move to the head office and other countries. It's like a snowball." (XMR)
		"We don't change the product for different types of customers. Training centers and hospitals [use our product] for their needs, universities for theirs." (SV)
		"If there is a new phobia, we can include it in the list [that physicians use for their practice] at the same price." (AT)
	Final user solution or integration	"Clinics are not the best customers for us. We see medical technology providers as partners." (AL)
		"Two ways of promotion: personal sales and teaming with partners." (DCL)
		"We want to be integrated into the business processes of our customers." (XMR)
		"We just show [a software] to the doctors […] and now we work with 2/3 of Finnish hospitals." (SV)
Development focus	Sector	"The areas of application for our service are very limited but can be adapted and in demand in the gaming market." (AL)
		"Technically we started as a support for the space industry [….] and telemedicine for these cases could become a very important part." (DCL)
		"Technically, it is easy to adapt to the new industry, but it is about your brand, how you position yourself." (DCL)
		"Private hospitals pay for us, final customers and state hospitals not at the moment." (PV)
		"The focus is on the rehabilitation [in the hospital] and home rehabilitation." (PV)
		"We concentrate on first aid, which means not only hospitals but firefighters, traffic accidents." (HS)
		"We work on a solution that is possible to adapt to different industries." (HS)
		"We increase the number of cases but focus on medical students." (B8)
		"Traditionally, we worked more with the B2B market but now look more on B2C." (XMR)
		"It is a challenge to move to a new area." (XMR)
		"One product that company is developing, one customer segment. […] We solve just one thing […] but training centers and universities are interested in buying licenses." (SV)
	Product	"We are developing a platform and will use it to develop applications for specific surgery" (AL)
		"[The solution] is like video conferencing, and on top of that, you can have augmented reality." (DCL)
		"We try to develop a service so that any patient with a special disease could download our solution." (PV)
		"[Company provides] training in the working environment, as hospitals don't want to send people for a long time for courses." (HS)
		"We build an ecosystem around our solution." (XMR)
		"You can see the problem from the 3D perspective. It will not be a surprise during operation." (SV)
Partner and customer collaboration	Personnel of state and private hospitals	"[A hospital as a partner] received a grant for developing [solution] and gave it to us." (AL)
		"My wife was involved in rehabilitation and that helped us in brainstorming." (PV)
		"It's very hard to receive a response from doctors." (PV)
		"Together with doctors working in the emergency room, we check what will be needed." (HS)
		"[Cases] are based on the facts from doctors." (B8)
		"Users and consultants are surgeons." (SV)
		"Doctors together with us prepare the training environment." (AT)
	Policymakers	"Not everything you can check with your doctor remotely […] legally he has to touch you and listen to you." (DCL)
		"The patient does not get any rehabilitation, s/he is out of the system." (PV)
		"Government does not pay for rehabilitation as they think that it does not help." (PV)
		"In the future, we will be able to use [AR] tools and we have to start educating the society." (HS)
	Insurance companies	

Table A1 (*continued*)

Design elements	Constructs	Quotes
Ecosystem view	Final users	"Remote prescriptions are not allowed in every country. This problem is related to legislation and insurance." (DCL)
		"It is a problem [to receive money for the service]. We are planning to make a joint project with [The Social Insurance Institution of Finland]; it should help to change the regulation." (PV)
		"Hospitals as our partners are happy as downtime reduces." (DCL)
		"Fifteen Nordic hospitals now use our software for the service that did not exist before." (PV)
		"We recommend that our customers record video and store it in order to make a knowledge depository." (XMR)
		"Collaboration with the final users is the key in our sales." (SV)
	Service or people approach	"Conventional teaching methods go digital." (AL)
		"No need to hire a nurse or come yourself to check if your grandmother took the necessary pills." (DCL)
		"For telecommunication purposes, a nurse [instead of a doctor] could be sent to a patient and, if needed, s/he would call a doctor." (DCL)
		"You still need a doctor, but you increase the therapy time." (PV)
		"Support of necessary knowledge once a month takes 10 minutes […] removing the instructor." (HS)
		"It's a new way of learning that complements a traditional one." (B8)
		"It's about organizational change for our customers or technicians." (XMR)
		"[Patients] receive a device, take it home, [and then they] don't need to go to a psychiatrist." (AT)
	Medical personnel and infrastructure	"No need to build new clinical train centers. […] You don't need to book them for 3–6 months." (AL)
		"It is hard to send technicians [immediately] to your clean rooms, and there are a lot of cases when you just need to change a module or connect a cable. It could be done by local personnel with a remote support." (DCL)
		"If you have a stroke, you can make individual exercises, and after that, you can do that with nurses or relatives." (PV)
		"[Our solution is related to] lack of qualified people for training." (HS)
		"Now we are developing a system where you can do everything yourself without assistance from the trainer." (B8)
		"It's a communication platform of the daily routine." (XMR)
		"Even more personnel could be involved in the case. You can share the image with people that were not available earlier, for example, in another country." (SV)
		"Reduction of medical personnel, visits to doctors" (AT)
	Speed and involvement in procedures	"This is a new ethical way to learn [to train medical personnel]." (AL)
		"You can fix your problem with a nurse quickly and remotely. […] If not, then you can send the right technicians with the right tools." (DCL)
		"Many older people are interested in such rehabilitation, so it can be called a game." (PV)
		"More simple training than in reality, less money" (HS)
		"Students have more knowledge after the course." (B8)
		"Work smarter, fix faster." (XMR)
		"There is no lag of time [in providing the result]." (SV)
		"Fifty percent reduction of therapy" (AT)

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