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Adoption of VR and AR technologies in the enterprise

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Abstract: The potential of virtual reality (VR) and augmented reality (AR) technologies for supporting business processes is well acknowledged in recent years. The objective of this study is to understand the current state of adoption of VR and AR technologies in different industries, and identify barriers and drivers for future adoption. The empirical data collection was made by semi-structured interviews with executives from both end user organizations and solution providers, where interviews and analysis were based on the Unified Theory of Acceptance and Use of Technology (UTAUT) -model. Based on the results, there is great interest towards VR and AR technologies and companies are impressed with both performance and possibilities of these technologies, but there are still significant practical barriers for adoption. Three main categories of use cases for initial adoption were identified, i.e. design, marketing & sales and training & simulations. Among them, design has most favourable conditions for adoption.

Keywords: Virtual reality; VR; Augmented reality; AR; Technology adoption; Technology acceptance; Unified theory of acceptance and use of technology; UTAUT.

1 Introduction

The potential of virtual reality (VR) was acknowledged already in 1999, when VR pioneer Fred Brooks, Professor of Computer Science at the University of North Carolina, did an extensive study on VR in engineering disciplines. Back then, he announced that ''*It [VR] now really works, and real users routinely use it*'' (Brooks, 1999). Now almost two decades later, we are still waiting for virtual reality and augmented reality to cross the 'chasm' to majority adoption. But what's different today, is that largest companies are increasingly pouring money into VR/AR start-ups, software infrastructure is improving to better support workflows to port 3D and CAD models to viewing in VR and the technology overall is starting to be mature enough for wider adoption.

The study focuses on acceptance and adoption of emerging VR and AR technologies. The purpose of the study is to identify the most potential use-cases across industries for the adoption and shed light on the barriers and drivers affecting the adoption process in each use-case. This problem is of interest currently, since VR is being adopted more widely across industries, but the rate of adoption will greatly differ between use-cases and industries. VR has also been subject to excessively positive expectations in the past and focusing on its disruptive potential, thus recent studies have been largely ignoring the practical application of VR in everyday use. Therefore, it is important to identify most favourable use-cases for faster adoption as well as recognize possible barriers.

Despite many promising results in earlier academic research, VR and AR are in the early adopter phase and companies are searching for use cases with tangible and measurable benefits for their businesses. The potential of these technologies has been validated in context of specific and individual use cases, but more general understanding of the most potential use cases across industries is lacking, and companies' readiness to adopt these technologies in practise is still unclear. (E.g. Brooks, 1999; Berg and Vance, 2017; Lawson et al., 2016)

There are two main research questions to be answered in this study. First, what are the main drivers and barriers for the adoption of VR/AR technologies in the enterprise? And based on that, which use-cases have the most favourable conditions for adoption? The study proposes three main classes of use cases for VR/AR adoption, and describes the drivers and barriers in each use-case based on the Unified Theory of Acceptance and Use of Technology (UTAUT) -model. (Venkatesh et al., 2003; Williams et al., 2015) The results indicated that among the main classes, Design has most favourable conditions for adoption, closely followed by Marketing & Sales, and wider adoption for Training & Simulations is still a few years away. The potential of use cases outside of these categories are also presented.

2 Related Research

Virtual and Augmented Reality Technologies

VR, AR, Mixed Reality (MR) or extended reality (XR) are considered as different positions in the same continuum of immersive computing, where real reality presents one pole and fully virtual environment the other. MR and XR are often used interchangeably to describe the range between VR and AR, and the boundaries will likely blur over time. However, today VR and AR are still very distinct technologies and solve different problems. VR provides immersion and it can be used to recreate new digital environments, but it occludes one's own surroundings. AR is the different side of that same coin. It is used to enhance natural surroundings by bringing digital content to real life environments. Current AR solutions on the market are still very far from having photorealistic digital images, thus current AR technologies are primitive and mainly used to bringing simple contextual information to one's view. In short, VR is the technology of choice for better visual experience and immersion, but AR provides mobility and enhances natural surroundings. However, the boundaries between these technologies will dissolve over time, and for that reason, we see that it is important to present the connection between these technologies. For this study, we focused on use-cases of VR and their extension to MR in the future. AR and its current applications are left outside of the scope of this study, because of their very different attributes.

The potential of VR to redefine current workflows is acknowledged in three main areas of use-cases; visualizations for sales and marketing, prototyping for design and simulations for training. First, visualization in VR can change the way projects are communicated, when 3D models can be transformed into a fully immersive virtual reality experience. It can be used as a sales tool to showcase large projects, where it can reduce the need to travel, and enables demonstration of unfinished projects. Second, VR has been used for design in advanced engineering for few decades already (Brooks, 1999), since it can make prototyping faster and cheaper by reducing the need to create physical mock-ups. Shen et al. (2010) demonstrated that designing in VR/AR could reduce time and cost, since objects can be modified in 3D space and interface is more intuitive and they can accurately create and edit objects with complex bases. Third, potential use cases have been identified in simulations and training use, where users experience a virtual scene or interact with virtual worlds. Here, VR can make learning more effective, because training is more intuitive, and reduce cost, because companies must rely less on expensive machines and reduce the number of training personnel needed (Bernardes et al., 2015; Gavish et al., 2013).

Design

Benefits of VR for design have been acknowledged decades ago, since reducing development of physical prototypes and enabling more iterative design process has tangible cost savings. Here, automotive companies have been in the earliest adopters. In automotive, there is a high pressure to constantly create new products and shorten the time to market, therefore VR is used to reduce time and costs, and increase quality in product development (Lawson et al., 2016). Daimler and Chrysler, for example, saw the value in using VR as part of their design process already in 1999, despite the technology was still primitive (Brook, 1999). VR can provide several benefits for automotive design. Berg and Vance (2016) explained that VR helps automotive companies to examine visibility (how the customer sees inside the car) and ergonomics (how reachable things are inside the vehicle), to spot possible errors and test different designs. In addition, aesthetic quality can be tested using VR, because advancements in lightning and material properties enable demonstration of near realistic products in VR. In the same study, A manager from General Motors mentioned, that ''VR has basically eliminated 3D prototyping'' (Berg and Vance, 2016). These same principles apply to product development in any company and experiments have been done in other engineering industries also (Fernandez and Alonso, 2015).

The benefits seem clear in principle, but problems still must be overcome to reach the desired utility. First, technology sets constraints for adoption in both hardware and software. Lawson et al. (2016) concluded, that development areas in automotive include higher resolution to work with details better, and improved haptics and motion tracking to study ergonomics more effectively. Berg and Vance (2016) had similar findings concerning hardware, and found also that model preparation and conversion are still problems related to software. Second, there are practical barriers for VR adoption. Establishing a VR laboratory is a significant investment, and professionals might resist change (Berg and Vance, 2016). They found that it was difficult to get engineers to try VR, but once they did, they were usually impressed, and most of the times, required only one session to prove the usefulness to their work (Berg and Vance, 2016).

Marketing & Sales

VR has great potential in marketing and sales, since it enables to 'look into the future' by looking at unfinished projects in realistic 3D environment. It also provides needed mobility to showcase large or otherwise immovable projects in a compact space anywhere in the world. Audi for example, decided to roll out a VR showroom concept, where physical cars are replaced with VR, from initial 100 to 400 new locations after successful testing. This enables them to have a presence in the centre of every city, where having large retail stores is too expensive. In addition to these self-evident advantages, there are other benefits sales also. Pantano and Servidio (2012) suggest that consumers can be more satisfied with virtual shopping experience and it creates valuable data for retailers. Their study demonstrated that virtual shopping environments can reduce cognitive load by providing intuitive interfaces and more customised experiences for customers. The same study also acknowledged the potential of virtual reality for marketing purposes. Companies can collect data from the shopping event and provide more customized experience for customers (Pantano and Servidio, 2012). An example of possible data collected from VR is eye-movement, which could be used to determine consumers' buying intentions (Bigne et al., 2016).

Training & Simulations

VR's greatest attributes, complete malleability, scalability and location independence, have enormous benefits in training and simulations. With VR, it is possible to recreate any operative scenario (e.g. driving expensive machinery) or dangerous situations (e.g. emergency training in case of fire) or transport users into a training environment that would be otherwise too remote to access easily (e.g. wind power turbine maintenance). This way VR can significantly reduce training costs compared to real life training. In addition, all of these scenarios need expensive machinery or trained people to execute, but in VR they are all easily and endlessly scalable. On the other side, there are videos, lectures, and other more passive ways of training. Here, VR can greatly increase learning effectiveness and retention, by making the experience more active and intuitive. (Bernardes et al., 2015; Gavish et al., 2013)

Healthcare

As aside from these three main classes of use cases, healthcare is one of the industries, where the use of VR has been studied extensively. Potential applications of VR in healthcare have been studied for 25 years, and first application for VR was developed in the early 1990s, when it was used to assist surgery planning (Chinnock, 1994). Nowadays, potential applications for virtual reality include rehabilitation and treating phobias or post-traumatic stress disorders (Gerardi et al., 2008; Howard, 2017), training surgeons to perform complex surgeries (Izard et al., 2017), visualization of images in 3D models and designing of surgeries (Robb, 2008).

Technology Adoption Theories

There are various models developed over the years to explain user acceptance and adoption of new technologies. One of the earliest of them and most widely known is the Technology Acceptance Model (TAM). When creating TAM, the purpose was to develop a model which is general enough, but applicable to explain technology adoption in different situations (Davis et al. 1989). Since then, TAM has been widely used in technology acceptance research, but its usefulness has been criticised due to its generic nature. Bagozzi (2007) reasoned that TAM is too simple model to predict user behaviour for various technologies in different situations, and he argued that researchers using this model have ignored the model's shortcomings. However, TAM has been often used as a foundation to subsequent technology acceptance models. For example, TAM2 was an extension to original TAM, where the most important difference to the original model was the consideration of social aspects in technology acceptance (Venkatesh et al. 2000). Other known theories in the context of technology acceptance are; the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB), a model Combining the Technology Acceptance Model and the Theory of Planned Behaviour (C-TAM-TPB), the Motivational Model (MM), the Innovation Diffusion Theory (IDT) and the Social Cognitive Theory (SCT). Each model has their own determinants for assessing users' behaviour, but many of these determinants were overlapping, so the need for unified model was found. (Venkatesh et al. 2003)

Unified Theory of Acceptance and Use of Technology (UTAUT) is a technology acceptance model that was developed by Venkatesh et al. (2003). It is a combination of those eight different models in technology and innovation adaptation and diffusion research covering wide range of disciplines from marketing and management to social psychology. The UTAUT model was empirically validated by Venkatesh, and it found to outperform all existing models. The UTAUT model was tested using original data from these eight studies and the new model explained 69 percent of the variance, while those original models explained only between 17 and 53 percent of the variance in users' behavioural intentions (Venkatesh et al., 2003). Since then, it has been extensively used and empirically validated in different technology acceptance studies. Williams et al. (2015) reviewed 174 of these articles that used UTAUT model and concluded that it was most commonly used for assessing specialized business systems and general-purpose systems. These applications of UTAUT include mobile banking, robot system, tablet PC, web-based virtual m-learning system and smart products, among many others (Williams et al. 2015). Therefore, UTAUT was chosen as appropriate framework for this study, because it has been validated in similar contexts, and because it is tested to outperform other technology acceptance models. In addition, it is not too general nor too complex of a model that many other models have been criticized for.

3 Research Design

Current and potential use-cases and applications of VR/AR were identified based on a review of academic articles. The adoption of VR/AR was studied as a case study using semi-structured interviews with executives and end-users of VR/AR. Case study approach was chosen for this study as a qualitative research method, because it is generally used to gain an in depth understanding about a phenomenon, and in contrast to other methods, case studies are more descriptive in nature. They aim to examine a certain situation or event from the perspective of the person studied (Hancock and Algozzine, 2006). Rather than trying to test hypothesis or prove relationships, case studies aim to identify themes and categories of behaviour, therefore case study research is usually more exploratory than confirmatory in nature (Hancock and Algozzine, 2006), and thus considered as a suitable approach for the emerging context of the current study.

The interviews were conducted using semi-structured method, and were based on the UTAUT-framework. Semi-structured interview method enables the interviewer to explore emerging responses and themes further, but also keeps a unified structure for comparable and transparent analysis. The study follows a case study approach, so rather than trying to test individual hypotheses or prove relationships, the aim is to identify themes and categories of behaviour, because this research is more exploratory than confirmatory in nature. (Keegan, 2009)

In the exploratory empirical part of the study, twelve people were interviewed. Interviewees were carefully chosen from various industries and from different functions, since the purpose was to get as broad coverage as possible of potential use cases for VR/AR. They either had been using VR/AR in their organization in some way, studied their possibilities extensively, or created solutions for these technologies. The UTAUT -framework is generally used to study the acceptance of a technology from the user's point of view, so questions were modified in interviews with developers and solution providers to prompt the impression they have had from the end users of VR/AR (i.e. their customers). It was acknowledged that responses regarding usefulness and ease of use might be biased when questions are concerning the systems that they are promoting to their customers. However, the view of solution providers and developers was considered especially valuable, because they had the broadest view of VR and AR in their respective sectors, and the very reason that they must sell their systems to end users, provides insight on what are the most common objections why people do not adopt VR or AR in their businesses. Each interview lasted typically from 45 min to one hour. During the interviews, extensive field notes were taken. Right after each interview, conversation was reflected on and a detailed description of that interview was created. Then, field notes were reviewed and sorted based on the research framework. The reflection and sorting of data after interviews was also the first round of interpretation for analysis. Now, the data from each interview was in a form that it was easily accessible for further analysis, and important themes from each interview could be reviewed in short order, when new data was acquired. The analysis of data was an iterative process that started after the first interview and continued in loops after clear patterns started to emerge and significant new data was not obtained anymore.

4 Findings

Based on the results, the use cases where VR/AR are currently adopted could be divided into three main areas: design, marketing & sales and training & simulations. Interviews were mainly focused on these use cases in VR, because AR or Mixed reality (MR) were not adopted to everyday use in respondents' organizations. However, the potential of AR and MR was still often recognized, and VR was seen as the first step to successfully transitioning to MR technologies in the future.

The results indicated that performance of VR was the biggest driver for adoption in each use case. This finding suggests that interviewees acknowledged the great potential of VR, which supports the view from secondary research that VR will be adopted more widely in the near future. However, *expected performance* is not sufficient to solely accelerate adoption, but other factors in the UTAUT -model must be considered also. With these other factors considered, design has the most favourable conditions for adoption followed by marketing & sales, and lastly, training & simulations had most barriers for adoption.

Design

Adoption in design related use-cases is most advanced and it has most favourable conditions for future adoption. It is a natural progression from 3D design in flat screens to more immersive environment. VR is used to complement traditional design process, but it has not replaced traditional working methods. Users adopting these technologies are still early adopters, and there are issues with conversions of models and general usability of VR interfaces. However, the benefits of these technologies already outweigh current difficulties.

> *It [VR] is the biggest revolution in our industry, since 3D design. (Head of yacht design and naval architect)*

There users are usually more technical people inside the organization, so adopting new technologies is generally more effortless for them and testing new technologies is also more encouraged among these professionals, therefore design was the only use case with positive *social conditions* for adoption. In addition, the *behavioural intention* to use was also strongest in design, because VR is a natural extension to current tools instead of completely new way of working.

Facilitating conditions still pose a barrier for wider adoption, because the workflow to port 3D objects from current 3D software applications to VR requires too much manual work. People in design were also the only ones concerned about the *trust* of VR systems, because these models contain lots of proprietary and sensitive information. In conclusion, drivers for adoption clearly outweigh barriers, and it can be assumed that adoption will accelerate when issues with workflows are solved, thus adoption will be fastest in design related use cases in the near term.

Marketing & Sales

Product or project visualizations for marketing and sales purposes have been among the first use cases of VR for many companies. These are generally static models from product concepts, finished products, development projects or real estate, for example. There have been identified two clear benefits when used VR as a sales tool. First, it can be used to provide more accurate information about unfinished projects, and second, it is location independent. Therefore, VR is best suited for situations, where the product or project is impossible to carry with or access, and in situations, where the project still under development. Visualizations are also the simplest way to incorporate VR in any field, because all that is essentially needed, is the model and a device to view it. Therefore, it is often the first experiment with VR for several companies.

VR can already provide quantifiable benefits, when used as a sales tool, but there are still barriers to overcome for wider adoption. *Facilitating conditions* are still the biggest barriers for adoption, because external help is often needed either in the development of new or conversion of old models. In addition, creating content can be too expensive, especially when made exclusively for one-time event. Therefore, it is proposed that companies should identify those use cases, where existing 3D models can be used as a VR model, or where the model can be reused multiple times, so that the cost of single use comes down. Another barrier is the *social conditions* for sales and marketing professionals, because they are generally less technical people in the organization and adopting new technologies most often less encouraged. Despite the barriers, *Behavioural intention* to use VR (which is the best determinant of future usage) was still positive in marketing and sales. This intention was driven by expected gains from better conversions for sales.

> *"It [VR] provides about 30 % of the overall marketing benefits in a project. (Sales and marketing manager, Luxury Real Estate/Construction)"*

There is also other important aspect for marketing and sales use cases, where the immediate benefits for using the technology are not clear, but it still serves a function for overall adoption of VR. Since these visualizations are relatively easy to implement, they are often just a way for most company to demonstrate 'innovator status' by showing these models in trade shows and events. VR still has novelty value, because the technology is in its infancy and most people have not experienced VR before. These demos are often done with only somewhat relevant content and VR in these cases is just another gimmick. It can be argued that these experiences rarely provide any positive returns for the investment, but they can still promote the overall adoption of VR, because they have seen to work as a gateway to more useful applications, such as training.

> *"The problem is that not many people have tried VR. VR or AR needs to be experienced for people to realise its possibilities. In one case, we made a product visualization for a customer, and when they saw the visualization, they realized how it could be transformed to training for product assembly, and asked us to create it for them. (Director of development, VR/AR Solution provider)*"

Training & Simulations

There is vast future potential in training and simulations, because it can be applied to any industry or use-case. Training in VR can reduce the need for expensive machinery for live training and eliminate the need for travelling to training locations. Virtual training environment is also modifiable, so it can be used to train for emergency situations or other rare events that are difficult to replicate in real life. These are also complex applications to execute in practise and have most barriers to adoption, so wider adoption is still a few years away. First, *facilitating conditions* pose significant barriers, because creating training applications is more laborious than only transferring static 3D models to VR. Second, insufficient *social conditions* for adoption seems to be the most significant barrier for adoption in training, which was reported to be due to lack of knowledge about these technologies. Therefore, *Behavioural intention* to adopt VR for training purposes is neutral, because the potential and interest towards these technologies is high, but barriers to adopt are still significant. However, the monetary benefits are tangible and interest to apply VR is clear, therefore the most forward-looking companies are already implementing VR training to their processes and others should start exploring also how immersive training could improve their business.

The empirical part of this research recognized the potential of MR and other use cases outside the three main categories, and most virtual reality use cases could be transferable to mixed reality when the technology advances. Among specific industries, secondary research highlighted promising advancements in healthcare. In addition, the technology currently progresses extremely fast in VR/AR industry, so other use cases, such as applications of remote assistance or virtual desktops, could be feasible in the near future.

5 Discussion and Conclusions

To the best of our knowledge, this study is among the first interview studies with executives and users of VR/AR technologies with the goal to identify most potential use cases for most favourable adoption across industries. Individual use-cases have been studied earlier, but extensive cross industry studies comparing different use cases have not been conducted before. This study also provides a framework to understand current use cases of VR/AR and to study potential future applications.

This study points out several new research areas. *First*, the value of MR is still unclear and it was not adopted for everyday use in respondents' organizations, thus this would be an interesting topic for further research. *Second*, adoption of VR/AR in other use cases outside of the three main classes studied here e.g. in healthcare where the importance of immersive technologies was recognized. *Third*, the importance of different components of immersive technologies, such as resolution, haptics, interaction (controllers) or voice. *Fourth*, this study provides a baseline for a more targeted research, such as studying adoption in a specific industry or use-case.

Executives and managers of end-user organizations could have ideas in which use cases VR/AR could have a positive ROI in their business and the possibility to transform current ways of working. The study also provides a framework that classifies the most promising uses of these technologies, which executives can use to identify applicable use cases inside their organizations. It explains why companies are initially using VR as a marketing gimmick, and why they should look past that, since its novelty value is fading and there are more productive ways to use VR. The study also present drivers and barriers in each class of use cases, which will help planning and preparation for the adoption of VR. In addition, results indicate why investing in VR is essential to prepare for future use cases in MR and for the immersive computing revolution, i.e. traditional screens replaced with immersive interfaces. For developers of VR/AR solutions, this study provide ideas in which use cases to steer efforts for most potential future adoption, and help to prepare for the challenges of integrating these technologies in end-user organizations.

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