A Spontaneous Adoption of AR Technology a manufacturing industrial context

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Abstract. Digital transformation is a process encompassing all organizations, requiring a proactive attitude and willingness to change. The Covid-19 pandemic highlighted the relevance of digitization through an increased awareness and implementation of digital tools for working life. The next wave of successful innovation in industry demands high-pitched adoption of technologies for production and workplace learning systems. Organizations are trying to understand which technologies to invest in, based on usability measures, cost effectiveness, and sustainability. It can be hard to predict which technology is best suited for specific tasks. This implies a growing risk regarding investments in technology. This paper describes the spontaneous use of technology for augmented reality (AR, Microsoft HoloLens 2) in a Norwegian manufacturing company during Covid-19. The case illustrates how AR technology can be used in assembling, installation and acceptance testing of machinery for selective soldering in the production of circuit boards. Data were collected through case study research and a qualitative research design, through observation and interviews with the participants. The results show that Microsoft HoloLens 2 is easy to adopt and could contribute to immediate and real value creation in industrial production companies. We believe that the spontaneous usage of AR technology in such extraordinary circumstances as a pandemic could motivate and guide other businesses facing important decisions related to technology implementation. The original value of this article is a contribution to the discussion on the Technology Acceptance Model, which is chosen as a theoretical framework for the paper.

Keywords: AR technology · Technology acceptance model · Industry 4.0

1 Introduction

Technological progress is growing exponentially, and the commercialization of modern technologies to the consumer market is steadily accelerating [15]. Thanks to global phenomena like social media, and not least unpredictable and critical events like the Covid-19 pandemic, modern technology is being distributed even faster. A wave of technological innovations affects organizations globally, and in the context of Industry

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4.0, companies must cope with phenomena like Internet of Things (IoT), digital twins, autonomous robots, and artificial intelligence [1]. Augmented reality (AR) has for some years been a part of this flow of new technology, and it is predicted that AR will play a key role in industrial development, especially in the areas of learning and skills training [2, 7]. To meet the demands for renewal, flexibility, and a sustainable production, industry must continuously implement new technology, which could become critical components of their competitive strategy. Making the right decisions for which technology to acquire and which models of implementation to use, and finding the potential for utilization, are resource consuming processes. Organizations must make a lot of considerations before technologies are put into operation, i.e., on technology characteristics, organization structure, management support, and human factors [3].

The purpose of the paper is to show how a complex industrial operation can be solved during extraordinary circumstances (Covid-19) through spontaneous use of new technology. This also illustrates the significance of collaboration and participation between various levels of the organization. Due to the pandemic and the encompassing restrictions a new and radical need for spontaneous usage of new technology has emerged. This paper describes a case where AR technology, already purchased by a company for research and learning purposes, gained new relevance due to the impacts of the Covid-19 pandemic. The case shows how a disruptive condition may force organizations to develop innovative decision models, skipping the usually essential steps of planning.

In the next sections we will elaborate the chosen theoretical framework, the Technology Acceptance Model (TAM), the give a brief introduction to AR technology, and discuss the applied methodology and the case of spontaneous usage of AR. Finally, we will try to contribute to the discussion about the technology acceptance model illustrated by the events of spontaneous usage of AR technology.

2 Theoretical Framework

As a theoretical framework for the present case, we are focusing on the technology acceptance model and spontaneous usage of technology. Here these two concepts will be briefly introduced. Implementing new technology in organizations can be challenging, and the success of implementation depends on how changes are planned, managed, accepted, and evaluated, and how the organization and its management consider the relation and the dynamics between technology and employees [14]. Various forms of decision-making methods in implementation of modern technology could be used, and different variables can be taken into consideration, e.g., size of investment, amount of affected employees, and the role of decision makers [13]. Decision making methods include identifying and choosing alternatives which are based on the values and preferences of decision makers [3]. Each decision maker must consider a variety of alternatives and make decisions which fit the goals of the organization.

2.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) [8] is influenced by the Theory of Reasoned Action [10], see Fig. 1. TAM is a commonly applied model to describe and measure an individual's acceptance of new information systems. The model was originally designed in 1986 and gained great interest in different scientific communities, leading to a substantial number of studies [4]. The main domain of TAM are two variables: Perceived Usefulness and a Perceived Ease of Use. Other variables was added by Venkatesh and Bala [16], including Social Pressure, Perceived Enjoyment and Fun, and Perceived Complexity.

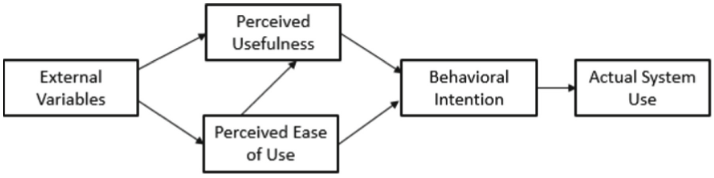

Fig. 1. Technology acceptance model (TAM) [17]

This paper focuses on the two basic variables of TAM adapted to innovative technology: the usefulness and the ease of use of AR technology (exemplified by Microsoft HoloLens2). Various studies have been performed on the use of TAM on VR- and AR adoption in learning environments and for the training on technical tasks [18–20]. Originally, TAM is studied on an individual level and not on the level of organizations. This is an important delimitation for this project since spontaneous usage of the technology primarily will be performed on the level of individuals, but within an organizational scope. This in turn implies that the use of the technology as a tool for training and learning will involve many levels of the organization, even if the practical application will take place on an individual operators' level. Assuming that the success of rapid implementation of modern technology in organizations can be caused by one employee's rapid decision to make use of technology, and that this employee for the management supports this approach, we suggest that spontaneous implementation of such technology can contribute to resolve a sudden event.

2.2 Spontaneous Usage

According to Oxford Dictionary [23] we define the adjective "spontaneous" as "not planned but done because you suddenly want to do it", or "done naturally, without being forced, practiced or organized in advance". "Usage" is defined as "the fact of something being used; how much something is used" [23]. If we merge these two terms, "spontaneous usage" can be defined as "the usage of something that was not planned to use before, but suddenly was taken into actual use." In the field of psychology, researchers are studying "spontaneous thought" [5] as an uncontrolled higher-order mental process which could arise in everyday life. The randomness of these spontaneous thoughts can contribute to the rejection of phenomena and cause them to never be realized. If we compare the terms spontaneous usage and spontaneous thought, we can assume that spontaneous usage, contrary to thought, triggers action. Thus, we choose spontaneous usage as a main term for the description of spontaneous action. In the next section, we will give a brief description of the AR technology used for specific cases.

3 The Technology

Augmented reality (AR) displays digital elements onto the real world, merging the virtual and the physical environment. Through AR the physical reality can be enriched and reinforced with digital layers and information elements, and new visual interfaces can be added to the physical surroundings. This facilitates interaction, information sharing and instruction in an interconnected and distributed manner [7].

In this paper we discuss the spontaneous usage of Microsoft's AR headset HoloLens 2 in an industrial context. Microsoft HoloLens 2 differs from AR in other contexts, like AR-apps on mobile phones, or head-up-displays in cars, in that the HoloLens 2 are a stand-alone, head-worn stereoscopic display equipped with processing power, sensors, camera, battery, etc. [22]. The headset has pre-installed software (Microsoft Teams, Assist, Guides), facilitating collaboration, instruction and guiding. There are some cons; the glasses are still restricted for professional tasks due to technical limitations, they offer a relatively small field-of-view (FOV), limited GPU and battery, and a mobile processor less powerful than AR-technology combined a pc.

4 Methodology

The described event coincided with the company's participation in a research project, including two other companies and partners from the public sector. This project is focused on the innovation, testing, and demonstration of systems for training, guiding, and learning using digital technology like AR and VR. Methodically, the study builds on a qualitative design approach, specifically based on case study design [9, 21] and collaborative action research approach [6, 12]. Case study research builds theory not as objective truth, but as interpretation of practical cases in their respective contexts. "The case study is a research strategy which focuses on understanding the dynamics present within single settings (…)" [9]. Data is collected through observation studies, field work and interviews. This approach encourages the active engagement of the actual users of the technology and close collaboration between these users and the researchers. This collaborative method proved useful when the company during the pandemic received a new machinery with high importance to keep production running, and the supplier's technicians could not travel from Germany to Norway due to Covid-19 restrictions. The acute situation hastened the company to find a solution, and encouraged the researchers to turn around quickly and participate in the session.

During the writing process, the researchers have been working with the implementation of AR technology in the company, actively observing and participating in the case. Interviews with participants were performed during and after the event.

4.1 Observation and Interviews

Date: April 20, 2021; Duration: 3 h; Participants: 3 technicians, manager of learning; Observers: CEO, PhD candidate, facility manager; Role of researcher: Observer, participant in some of the conceptual and technical preparations; Number of interviews: Three, the learning manager, two technicians.

TAM was used to analyze and sort results, not least to document the extent to which the employees found the technology useful. See Fig. 1 for an illustration on how the project followed the five steps in the TAM-model.

5 The Company and the Case

The case company was established in 1973, its core production is in industrial electronics, i.e., circuit boards, smart chargers, and communication components for the petroleum industry. The 22 000 sq. m. production facilities are co-located with the administrative functions in Eastern Norway. The company is one of several Norwegian Centers of Expertise (NSE), and has a total of approximately 250 employees, and reached 598 MNOK in sales in 2020. The case company is a part of the innovation project FAbL (Faster Assembly by Learning), described under"Acknowledgements". In the following chapter the spontaneous usage of AR technology will be described.

5.1 Case: Real-Time Augmented Instruction for the Assembly Machinery

The case shows a spontaneous usage of AR technology for the installation and acceptance testing of production machinery. In 2020, one of the participating companies in the R&D project FAbL purchased a fully automated machine for selective soldering for the production of circuit boards. Assembling the parts of the production machinery is an extensive series of tasks, requiring high competence in mechanics and electronics. These tasks include assembling of mechanical and electronic parts and circuits, installment of computerized systems, and final accept testing of all functions. All this is performed by trained technicians, guided by the German manufacturers' experts on the field, usually spending some days in Norway during the installation and testing. However, due to Covid-19, the manufacturer's technicians were prevented from travelling, and the case company's staff were unable to install the machine without the assistance from the German experts. New routines had to be established in a hurry, as the soldering machine was essential for maintaining the production capacity.

By a coincidence, the case company had acquired a pair of AR glasses (Microsoft HoloLens 2) due to their participation in the FAbL project, exploring digital technologies for faster assembly by learning. The company's manager of learning had a brief knowledge of AR technology after some testing, and he saw an opportunity to simultaneously solve the assembly situation and get more data on the use of AR for spontaneous instruction. He gave a couple of the factory employees a crash course in the use of HoloLens 2 and the Assist/Teams software. Through this, they could have instructions and mixed reality annotations in an "immersive digital meeting" during the installation of the soldering machine.

The technicians mastered HoloLens 2 after 2 h of on-site tutorial by the manager of learning. The German expert was then invited to a Teams meeting through the AR-glasses, and was given a quick tutorial on how to use the tools and functions for instruction and annotation in the meeting app (the software Assist works through Teams). Then they started the augmented collaboration and assembly process. During the session, the CEO of the company participated both through the Teams-meeting in the HoloLens 2, and physically through visits to the premises. This provided a unique opportunity to "live audit" the installation of the machinery.

Experiences from the manager of learning:
Quote 1: "During the installation, I did not wear the glasses myself, but the technicians told me that they experienced an immersive proximity to the instructor seated in Germany. Eventually, we became more confident that the technology worked as planned. Overall, we experienced that HoloLens 2 was a key factor in assembling and getting the machinery up and running."

Quote 2: "Several other machine suppliers now are considering shipping HoloLens 2 with their machines, to instruct and communicate via AR during assembly, installation, and accept testing. During Covid-19, we experienced that the cost of a AR headset equaled the cost of shipping two technicians from Germany to Norway. The investment is then estimated to have been saved in at the first installation."

6 Findings and Discussion

The case is evaluated using TAM (Fig. 1), level of spontaneous usage, and rapid implementation. The objective was the study of two main variables: Perceived Ease of Use and Perceived Usefulness. Due to the company's participation in project FAbL, they were familiar with the AR technology and HoloLens 2 before the spontaneous event. The manager of learning is a technology enthusiast and worked in advance on utilizing the AR glasses for simple tasks, like making a guide for the use of the copier. Based on this, and collaboration with the IT department, he observed that the usage of AR technology could be done without great technical thresholds. A challenge was the coupling between the AR technology and the organization's IT system, and between the AR-software Teams, Assist and Guides and the user's MS business account. Solving these challenges, the glasses were recognized as a specific computer on the company's network. Regarding the parameter Perceived Ease of Use, we can conclude that a strong individual interest in technology, familiarity with the organization and easy access to managers and a variety of companies' human and technical resources played an essential role in the case event.

We experienced that the Perceived Usefulness was affected by the Covid-19 situation, and that the spontaneous usage of technology in the case event was partly due to the strict rules for travel and entry between exposed countries. Additionally, the avoidance of expenditures due to already possessed AR equipment may have amplified the perceived usefulness. The perceived usefulness on an individual level seems to be lower than on an organizational level. Previous studies on TAM are generally focused on individual experiences and perceived usefulness [19]. Our results may indicate that TAM should be more studied on an organizational level, not least related to the implementation of modern technology in an Industry 4.0 context.

7 Conclusion

Technology implementation is usually a time-consuming process. A quick summary of the results reveals that the following variables played a significant role in this case: The

Covid-19 context, one enthusiastic employee's interest in AR-technology, the management's belief that this was profitable and substantially important for innovation, and the employees' and the organization's ability to convert these variables into action. The study encompasses only one event of spontaneous usages of AR technology, and in just one single company. Considering these limitations, the reported findings may open for new discussions on faster adoption and adaptation of innovative technology in organizational practice. The case offers some evidence that the spontaneous utilization by one single individual may support faster adoption of modern technology at an organization level. Although spontaneous usage proves to be particularly suitable under certain conditions, more experience is necessary to figure out if this provides an interesting path for further research. We suggest the following guidance: What is the role of the individual (the technology enthusiastic employee) in the implementation of modern technology? Which role does spontaneous usage play in the TAM model? How can the TAM model be used on an organizational level?

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