The early stages of extended reality

An analysis of the opportunities and challenges faced by early stage
businesses within the extended reality (XR) industry

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Abstract

In recent years, the extended reality (XR) industry has witnessed remarkable growth, revolutionizing various sectors. The potential of XR to reshape industries and create new business opportunities has captured the attention of entrepreneurs and investors alike, leading to the emergence of numerous early stage businesses venturing into this exciting field. Despite the promising prospects, the XR industry remains in a dynamic and evolving state, presenting both opportunities and challenges for early stage businesses seeking to establish themselves within this competitive landscape. This master thesis aims to explore the experiences of early stage businesses within the extended reality (XR) industry, with the goal of understanding the opportunities and challenges they encounter in the current period of study, spring 2023. The study takes a qualitative research approach, employing observations of early stage XR businesses and semi-structured interviews with professionals within the industry and academia of XR. The analysis is based on thematic analysis applying Disruptive Innovation theory and Adoption Curve Theory combined with Gartner's Hype Cycle. Together with existing literature the analysis creates a picture of the current opportunities and challenges that exists in the XR field, visualized in a prototype of a 3D mind map. These range from areas such as recruitment, financing and technology development to user adoption, ethics and inclusion. They reflect what businesses are facing in early stages of a relatively new industry as well as some of the political, economical and sociocultural factors. Some of the opportunities are high potential to transform and disrupt industries and markets, creating new ways of interacting in virtual worlds as well as new revenue streams. Some of the challenges are low adoption, funding issues and competition with leading players. Ultimately, the research provides valuable insights of the XR industry which could be used when making strategic decisions for professionals and stakeholders.

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1. Introduction

Extended reality (XR), is a universal term inclusive to immersive technologies encompassing virtual (VR), augmented (AR) and mixed (MR) reality technologies. These technologies have emerged with significant growth and the potential to revolutionize many industries and aspects of society and life (Shwetha & Yashas, 2022). Apart from the ongoing global digital transformation, the COVID-19 pandemic contributed to the accelerated adoption of XR technology in various industries, leading to increased demand for remote collaboration tools and virtual alternatives to traditional media (Matthews et al., 2021).

XR can provide immersive and engaging experiences in various industries (Bezegová, 2017). For example, in the entertainment industry VR has been used to create immersive experiences, such as VR cinemas and theme park attractions. In healthcare, XR technology has been used for patient rehabilitation and medical training, while in education, XR technology has been used to create interactive and creative learning experiences. In manufacturing, XR technology has been used to simulate factory layouts and job training in more safe and controlled environments. In the fashion and retail industry, customers can interact in virtual showrooms with products in a more engaging way (Bezegová, 2017). AR can also overlay relevant information onto real-world environments, enhancing understanding and context. In many ways, XR can be used to change understanding and behavior, in a more effective way than traditional media methods (Pitt, 2019). In terms of consumption, using XR can lead to increased brand awareness and loyalty as well as higher sales.

Advances have made XR technology more accessible to creators, leading to increased investment in the industry and the creation of new hardware and software solutions (Bezegová, 2017). As a result, there has been a surge of interest in XR technologies in recent years which has led to an increase of businesses in the XR field (Alnagrat et. al., 2022). Current leading players in spring 2023 within the XR market are Meta and Microsoft, which offer solutions within VR and AR such as headsets and glasses (Metaquest and HoloLens). They also offer metaverse platforms for interaction in virtual worlds such as Horizon and Mesh (Statista, 2022a).

The XR industry is at the forefront of technological innovation, constantly evolving and expanding, with new and emerging technologies driving innovation and growth. Some of the key technologies that are expected to have a significant impact on the XR industry in the coming years include Artificial Intelligence (AI), 5G and later 6G (Huynh-The, 2023). By staying up to date with the latest trends and technologies, businesses can develop strategic plans and leverage their technology. Despite the potential for significant growth and innovation in the XR industry, businesses face numerous challenges and opportunities in building and scaling their ventures (Bolter et al., 2021). To understand the industry dynamics and trends, develop effective business strategies, and overcome significant operational and financial obstacles - XR businesses could navigate these challenges and capitalize on emerging opportunities. By understanding the experiences of XR businesses, we can gain a better understanding of the industry as a whole.

1.1 Market growth and segments

The XR industry can be segmented into several sub-markets, including hardware (head-mounted-displays, HMDs, sensors and other physical devices used in XR experiences), software (includes tools and platforms used to create XR content), and services (includes consulting, training and support services). It can also be segmented by application, with VR, AR and MR (Langer, 2023). The technology can also be segmented by industry (Bezegová, 2017). From gaming, entertainment, education and tourism to healthcare, engineering, eCommerce and architecture, XR has the power to create immersive and engaging experiences in various industries. Sectors expected to witness the most disruption by immersive technologies according to XR industry experts worldwide in 2021 are Healthcare & Medical devices, Marketing & Advertising and Education (Statista, 2022a).

The global extended reality market is valued at USD 42.83 billions in 2022 and is projected to reach a value of USD 345.09 billions by 2030 at a CAGR (Compound Annual Growth Rate) of 29.80% over the forecast period (Statista, 2022b). VR is expected to account for the largest share within the XR market by 2030 (Statista, 2022b). This is due to the widespread adoption of VR technology in industries such as gaming and entertainment, and lately there have also been growing use of VR in healthcare and education (Fortune Business Insight, 2022). AR is also expected to grow at the fastest CAGR during the forecast period 2022-2030

(Statista, 2022b). This growth is mainly driven by the increasing use of AR technology in mobile applications and in the retail industry (Researchdive, 2022). The MR market is currently smaller than both VR and AR, but is also expected to grow. This development is driven by the adoption of MR technology in industries such as manufacturing and logistics (Bloomberg, 2023a). The average price of a VR headset in the United States was 430 U.S. dollars in 2022, and is expected to remain at around this price in the following years (Statista, 2022c). Although it is expected that Apple will release new lightweight AR glasses, lower cost versions of MR headsets and glasses are also in development (Bloomberg, 2023b). The global market is expected to grow considerably in the coming years (Statista, 2022b). Currently the North American region has the biggest market share in the XR market, but the Asia-Pacific region is expected to register the highest compound annual growth rate. This is driven by factors such as the growing adoption of XR technology and the increasing investment in XR technology by companies in the region (Fortune Business Insight, 2022).

1.2 Purpose, objectives and research question

The XR industry is relatively new but rapidly growing, which is reflected in the research field. There is little research on the challenges and opportunities XR businesses are facing when growing their businesses and developing their technologies. Especially, there is little research on the early stage XR businesses which followingly will be focused in this study. This is a significant gap in the research that requires deeper understanding of the field. It also needs to be addressed in order to ensure that the XR technology as well as the industry and businesses within are able to reach their full potential. We aim to fill this research gap and to make an original contribution to the field by examining the experiences of early stage XR businesses and XR professionals, with the goal of providing valuable insights for businesses and stakeholders in the industry. This thesis aims to explore the opportunities and challenges within XR by observing early stage XR businesses and interviewing professionals working and educating within XR. By observing early stage XR businesses we can gain a unique understanding about what opportunities and challenges they see as of spring 2023. We look at the technology itself as well as aspects such as social and ethical.

RQ: What opportunities and challenges are experienced within XR?

Studying XR as a whole offers a more holistic and forward-looking approach to understanding the opportunities and challenges in the immersive technology landscape, which is the aim of this study. There is a growing trend of convergence in the XR industry, where these technologies are increasingly integrated. This allows researchers to capture the synergies between these technologies and identify emerging trends that may not be evident when studying VR, AR and MR separately. XR is a multidisciplinary field, and studying it holistically encourages the exchange of knowledge and insights across different domains. Lessons learned from one XR technology may be applicable or informative for another.

1.3 Terminology

- Extended Reality (XR): XR is a term that encompasses Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) technologies (Shwetha & Yashas, 2022)
- Virtual Reality (VR): VR is a simulated environment created with computer technology, which enables users to experience a different environment as if they were physically present in that environment (Farshid et al., 218).
- Augmented Reality (AR): AR is a technology that superimposes digital content, such as images, videos, and 3D models, onto the physical world (Farshid et al., 2018).
- Mixed Reality (MR): MR is a technology that combines elements of both the physical and digital worlds to create a seamless and interactive experience. MR merges real-world and virtual elements in real-time, allowing users to interact with digital content as if it was physically present (Farshid et al., 2018).
- Metaverse: a virtual world where humans, as avatars, interact with each other in a three-dimensional space that mimics reality (Cambridge Dictionary, 2023c)
- Industry consists of the companies and activities involved in the process of producing goods for sale, especially in a factory or special area (Cambridge Dictionary, 2023a).
- Market refers to the business or trade in a particular product, including financial products (Cambridge Dictionary, 2023b)
- Early stage businesses refer to startups and other entrepreneurial ventures in the initial stages of their development (Investopedia, 2022).

2. Literature review

When finding relevant research on the topic, the databases used for searching are Google Scholar and Malmö University Library's database LibSearch (EBSCO host). This helps us find out what is scientific and peer-reviewed but also accessible both physically and online. To increase the chances of finding relevant studies, and filter out the search results, search terms are specified. Examples are writing XR OR "extended technology "AND industr* or market*, and variating the word *startup* with *early stage business*, *sme* and *business*. As we are in contact with many professionals from industry and academia in the XR field, we also ask them for literature recommendations.

This literature review explores the current research on the XR industry and technology, and provides insights when looking into what opportunities and challenges there are within XR. Key concepts for this literature review include XR businesses, XR industry, XR technology, remote collaboration and immersiveness, related technologies as well as adoption of XR technology. When investigating the current literature and research we also look into what could relate to opportunities and challenges, such as related to the XR technology itself and the industry.

2.1 Current research on opportunities and challenges of XR

To look at the XR industry from a broader view we aim to understand the field from different perspectives, such as technological-, business-, user-, sociocultural-, legal- and regulatory perspectives. In the book Reality Media, written by Bolter, Engberg and MacIntyre (2021) they are comprehensively exploring the past, present and future of VR, AR and how it affects the physical and social reality. Physical reality consists of entities and facts that are genuinely objective, existing independently of our representations of them. Social reality consists of entities and facts that instead are an outcome of a process of social construction and interpretation (Brey, 2014). Bolter et al. (2021) explore how XR technologies are changing people's relationship to reality and to the media, looking at the social and cultural implications such as when communicating, learning, working and playing. One of Bolter et als (2021) findings is that XR is growing rapidly in a variety of industries such as gaming, health and the industrial sector, which enables new markets and opportunities for XR

businesses. Another is that large companies such as Apple and Google are investing heavily in XR. XR will likely play an increasingly important role in society and our lives in the future and transform different aspects of it.

The current market is still in its early stages with technologies and applications which makes room for innovation and growth (Bolter et al., 2021). However, the market is highly fragmented, with companies and technologies competing for market shares, which makes it difficult for consumers to navigate the landscape and for companies to establish themselves as leaders in the industry. At the same time Bolter et al (2021) states that the fragmented nature of the XR market creates opportunities for businesses and technologies to emerge and disrupt the market. Fragmented markets are also advantageous for small businesses because there is little barrier to entry, in comparison to concentrated markets which have fewer but larger firms that serve the market.

The authors suggest that the XR industry and market is still evolving rapidly, with many opportunities and challenges ahead (Bolter et al., 2021). Some of the opportunities of XR are related to the potential transformation the technology has on society and life. These technologies could help address challenges such as social and environmental challenges, for example by enabling remote work and reducing the need for travel. Some of the ethical and political challenges the authors mention are privacy and security concerns, given the potential for XR to collect and use sensitive data. Also how it may have an impact on social inequality and potential for addiction. As the technologies become more widely adopted, it will be important for stakeholders such as regulators and developers to address these challenges and collaborate to create a more sustainable and equitable future for XR. Other challenges brought up are the high cost of XR technologies and the need for specialized hardware and software that could limit adoption among both businesses and consumers. Also, the lack of standardization could make it difficult for developers to create applications that work seamlessly across different platforms and devices.

Furthermore research by Novakova and Starchons looks at challenges and opportunities in XR technology within creative industries (2021). The authors state that XR technology can help enhance user experience and thus revolutionize various forms of media such as gaming, art, film and music. For example the research presented is held with french artists who got the opportunity of testing an AR mobile application on various artworks from artists. According

to the authors, this and other cited research projects, shows that "the acceptance rate of the XR technologies by the informed audience strongly predominates over its penetration in such population which can be interpreted as significant market opportunity" (Novakova & Starchon, 2021). The adoption of XR technology in creative industries is also creating new markets with new opportunities for entrepreneurs and investors. The authors also state that XR can unlock new forms of content creation, by allowing creators to experiment with new forms of storytelling, visuals and interactivity. XR can also help with providing users with more engaging experiences, which increases user engagement and creates better monetization opportunities for creators and companies.

The paper also lists some challenges that arise with the use of XR technology. With new technologies comes new skills that are required to produce content (Novakova & Starchon, 2021). This is a challenge for content creators which may lack the necessary expertise or resources to produce content for XR and fulfill new increased demands from customers. Another challenge that is stated in the article are technical challenges, as XR technology needs investment in both hardware and software development. The XR technology also has regulatory challenges ahead related to legal questions such as intellectual property, privacy and also safety as it is currently missing or poor. According to the authors, policymakers will need to develop a legal and regulatory framework to ensure responsible development and use of XR. Regulations are something that are stated as missing or not applicable enough for current XR technology, which is something that we would like to look at further, as it might have impact on the technology itself and the industry stakeholders.

Novakova and Starchon (2021) also discuss the importance of collaboration between different stakeholders in the industry. The authors state that successful adoption of XR technology requires collaboration between different stakeholders including creators, developers, investors and policymakers. Developers and creators are responsible for creating compelling XR content. Also, investors play just as critical a role by providing financial resources for the development of XR technology and content itself. Investors must collaborate with developers and creators to identify opportunities for investment, as well as providing funding to bring the opportunities to life. Policymakers and regulators also have their role to play within the XR industry. They also have to collaborate with creators, developers and investors to ensure that the use of XR technology will be safe and ethical while also compelling with already set laws and regulations.

To further understand the XR industry and how it can change how business operates, literature by Marr (2021) is explored on how consumers are approached and how business can tackle engagement problems. The author agrees that the XR field is rapidly developing with a wide range of different applications across different industries and areas. The key benefit with XR is the ability to create immersive and interactive experiences, which can enhance learning, training and even collaboration. VR can for example provide realistic simulations of complex or even dangerous situations that can be used for safer job training, while AR can be used to overlay digital information onto the physical world. This can help with understanding complex concepts or even to visualize products. The author then discusses the future potential of XR, stating that it's destined to continue to develop and also expand into new industries and areas. As both XR and other emerging technologies improve, so are the immersiveness and realism. This can allow for new and improved forms of entertainment, education and remote interaction and collaboration. Marr (2021) also states that XR has the potential to transform the healthcare industry, while stating medical training, remote consultations and virtual surgeries as examples of how XR technology can be used. In the article some challenges for the XR technology that needs to be addressed before unlocking its full potential are also introduced by the author. These are challenges such as cost, accessibility, privacy, safety and inclusive and diverse design considers the needs of different users (Marr, 2021).

2.2 Increased need for remote collaboration and immersiveness

The use of XR technology has, as stated before, become more important during the Covid-19 pandemic as remote collaboration, communication and learning became almost fundamental alternatives (Matthews et al., 2021). Much energy has been focused on the transformative influence of the Covid-19 pandemic and whether these changes and advancements will stay the same or continue. The transformation of communication and collaboration from distance relies on convenient and accessible forms of remote presence and interaction. During the pandemic period the name Zoom became a much more used verb, and with it came the phrase ''Zoom fatigue'' which helped characterize the exhaustion felt during long and boring sessions in video calls. This showcased a greater need for more immersive and engaging remote collaboration alternatives, where XR can be seen as an opportunity by developing

new and more immersive collaboration tools. During the same time period some other teams and businesses with better resources made use of these XR based tools instead of video calls during meetings and collaboration. This also further highlighted the difficulties and limited penetration the technology had but at the same time it offered insight into the efficiency and maturity of XR (Matthews et al., 2021).

Facebook has already started to position themselves in the market with devices for gaming and content platforms, but achieving a stronger sense of immersion during social interactions within XR is still a key part of their future plans and development (Matthews et al., 2021). However, achieving the feeling of ''presence'' during virtual interactions is very challenging no matter the business. One of the reasons for this is the current limitation of the available technology when it comes to creating realistic avatars. This is also one of the reasons why many VR games and applications are designed for single users. Many research programs in the industry are dedicated to addressing this issue, partly by developing more photorealistic representations of users. According to Ens et al. (2019), the research into the use of XR with the purpose of collaboration has unfolded over a period of three decades. However, creating a sense of presence in virtual environments is still a work in progress. The challenges are the social cues such as body language, facial expressions, tone of voice and other non-verbal cues that play an important role in interaction between humans.

XR approaches need to address this by increasing the clarity of the interactions, and allowing the users to moderate their interactions. This could be achieved by enabling users to walk around, modify the proximity to other avatars, and enabling users to use hand gestures (Matthews et al., 2021). These components can in itself enhance the sense of presence and increase the fluidity in the interaction. However, simulating human interactions in a way that is both immersive and natural is still a major challenge for designers and developers in the XR industry. Achieving the feeling of presence is not just about creating more realistic avatars, but also about how the users collaborate in the virtual environment. The designers and developers need to consider the complexity of simulating human interactions and create environments that are both engaging and enjoyable for the users.

While discussing the expanded use of the XR technology the ethical dimension must also be taken into consideration. Within the technology and its use are clear dangers in the development of photorealistic impressions of human avatars such as identity theft, negative

physiological impact created by self-perception and body image such as weight perception. In the article Matthews et al. (2021) wonder how we can ensure that XR technologies are designed to include the greatest number of different people while at the same time doing the least harm possible, while also asking the question about how to use the opportunity to help people with disabilities and mental conditions such as autism, obesity, dementia, alzheimer and other marginalized groups in the society. To solve these questions the authors indicate a role for inclusive design that must be human-centered instead of located in the technology. The goal of inclusive design is to cultivate designers who have experienced these barriers and can develop solutions that address diverse needs and create inclusive XR experiences. What needs to be produced is not a uniformed set of individuals that has specific competencies, but instead a group of individuals that works together as a team where each can contribute with a diverse perspective (Holmes, 2018). Inclusive design considers diverse users to drive innovation and create better experiences for all participants, which increases the commercial potential of the product or service.

The rise of XR technology is connecting people in a unique way where complex questions about design choices and industry practices impact needs to be managed. Recent research has already been investigating complicated matters when it comes to presentation in virtual places, such as the use of avatars as extensions of the users embodiment in XR, where social mechanics are key considerations (Matthews et al., 2021). It is clear by looking at the established players in the area, such as Spaces, MeetinVR, AltspaceVR and Facebook Horizon, that the application of XR for remote social presence is in its early stages. However, the technology is moving forward towards more maturity as well as moving towards a closer representation of human movement and more personalized avatars.

2.3 Integrations of new technologies with XR

There are other new technologies that are emerging in parallel with the development of XR. Maksymyuk et al. (2023) discusses AI, 5G and the future 6G that is becoming more and more integrated in technology which has a lot of synergies and could be used to complement XR. There have already been research and case studies about how these technologies, together with XR, can impact society and continuous development.

AI has the potential to revolutionize the XR industry by enabling more intelligent and sophisticated experiences (Maksymyuk et al., 2023). At its simplest form AI is described as a combination between computer science and robust datasets, which enables problem solving (IBM, 2023). AI algorithms can be used to analyze user data and create personalized experiences based on individual preferences and behavior. It can also be used to power chatbots and virtual assistants in XR environments, providing real-time information to users. Reiners et al. (2021) continue by pointing out that AI can enhance object recognition and be used to track movements and objects, improving accuracy and realism in virtual environments. It can detect and track the user's hand movements, allowing for more fluid and natural interaction with virtual objects.

The research of Hadziselimovic (2023) is expanding the notion of cyber crimes from AI crimes to extended reality crimes, given the rise of the metaverse. Several ethical challenges arise in the context of AI: 1) There is lack of transparency of AI tools. The decision-making processes of AI systems are not always clear or understandable to humans. This opacity can make it difficult to assess how AI arrives at its conclusions or judgments. 2) AI is not neutral: AI-based decisions are vulnerable to inaccuracies and can lead to discriminatory outcomes. Biases can be unintentionally embedded or deliberately inserted into AI systems, raising concerns about fairness and equity. 3) Surveillance practices for data gathering and court user privacy: The use of AI may involve extensive data collection and surveillance practices, potentially compromising the privacy and confidentiality of individuals interacting with the court system. 4) New concerns for fairness and risks to Human Rights and fundamental values: The application of AI in court proceedings raises new concerns regarding the fairness of decisions and potential risks to fundamental human rights and other core societal values. These ethical challenges highlight the need for careful consideration and regulation of AI technologies in the legal domain to ensure transparency, fairness, privacy protection, and the preservation of essential human rights and values.

Hadziselimovic (2023) is investigating current legal systems and how ethics of care could be applied on XR. A well-regulated metaverse and social media environment, governed by appropriate legal frameworks, holds the potential to serve as a democratic tool. It can empower users within the metaverse to exercise freedom of expression and provide access to information through an advanced system of jurisprudence. Such a regulated environment would enable individuals to express their views openly and ensure equal access to

information, fostering a democratic culture within the metaverse. However, it is important for XR users, including those in the metaverse, to recognize that along with their rights they also have responsibilities. This includes abiding by legal restrictions that protect the privacy rights of other users. Despite entitlement to freedom of expression and access to information, users should be mindful of the boundaries and respect the privacy of others. Upholding these responsibilities ensures a balanced and respectful social media and metaverse environment where privacy rights are safeguarded. Although the paper of Hadziselimovic (2023) concludes by reviewing possible international open justice scenarios for XR criminals, this study will not go further into the topic of regulations and punishments. However we are interested to see what opportunities and challenges there are on XR when it comes to regulations - what there is or is missing, how to decide them and who should decide them - as there are more stakeholders than only the users of the technology.

The emergence of 5G networks is also expected to have a significant impact on the XR industry, enabling more sophisticated and bandwidth-intensive experiences (Maksymyuk et al., 2023). 5G networks can provide faster and more reliable connectivity, allowing for real-time streaming of high-quality XR content. According to Alriksson et al. (2021), this can lead to a more seamless and immersive XR experience that is not limited by network constraints. 5G is a major driver for XR, since it can help to scale up the experiences so it supports a larger number of users with time critical communication. 5G will also start enabling network slicing and edge computing. Edge computing can be used to reduce latency and improve synchronization between the physical and virtual worlds by processing the data closer to the source of that specific data, instead of sending it all the way to a central data center or cloud. This reduces the time it takes for that data to be transmitted and processed, creating smoother and more responsive experiences. Network slicing refers to dividing a single physical network into multiple virtual networks with their own set of performance characteristics. An XR application can then be allocated, depending on its specific requirements, a dedicated slice of the network which ensures stability (Alriksson et al., 2021). The author continues by stating that with the help of 5G, XR is expected to even further improve productivity and convenience for consumers, enterprises and public institutions in areas such as entertainment, training, education, remote support, remote control, communication and virtual meetings. It is expressed that it can be used virtually in almost all industry segments such as health care, real estate, shopping, transportation and manufacturing.

Looking even further into the future, 6G networks are expected to provide even faster and more reliable connectivity, as well as more advanced features such as holographic communication, which refers to real-time capturing, encoding, transporting and rendering of 3D representations, and immersive telepresence. Allam & Jones (2021) argues that 6G can, when it's available, enable faster and more reliable connectivity which could synergize with XR technology. It can enhance its capabilities by creating more engaging, realistic and immersive experiences which are seamless compared to current wireless networks. XR technology does require a lot of processing power to deliver experiences, and 6G can help by offloading some of the processing to the network. In return, this makes it easier to create more complex and immersive XR experiences, and makes it more realistic in the process. By having faster and more reliable connectivity, as well as better processing abilities with more precise location and position information, XR technology can create experiences that are more closely tied to the user's physical environment (Allam & Jones, 2021). Beyond helping with connectivity and computing power, the authors also argue that 6G will help XR when it comes to localization and positioning within immersive experiences. Ultra-wideband technology is seen to be a major feature when it comes to 6G technology, and the authors explain that this will help XR with precise location information. This will help to create XR experiences that are a lot more closely tied to the user's location, such as AR applications which overlay digital information onto real-world objects for example. They also mention that 6G will improve network slicing, which means that XR applications can be prioritized on the network, ensuring they receive enough bandwidth to have a more seamless lag free experience.

The authors explain that the development of 6G and XR technology will have a role in future digital, smart and sustainable cities (Allam & Jones, 2021). One way in which 6G and XR will impact is that it can enhance urban experiences by improving urban planning and design. XR could be used to create virtual tours of historical sites, or to provide real-time information about public transportation. By creating virtual models of the city, XR could, with the help of 6G, be used to simulate scenarios so the resources could be optimized. Buildings could be remade in XR, allowing planners to visualize different designs and assess the impact on the surrounding environment. A disadvantage with 6G is that the increased speed and reliability of the networks requires more energy, which can lead to high energy costs for users (Allam & Jones, 2021). Also, the costs associated with building and maintaining the networks could

become too expensive for some regions and countries. The high costs are already part of the reason that technology adoption is lagging with 5G.

2.4 Adoption of XR

Numerous different fields and industries such as education, gaming, healthcare and manufacturing have recognized XR's potential and tried to incorporate it (Chuach, 2019). However, that author states that despite all the research and headlines about XR's potential, the technology still struggles to gain attraction among both consumers and enterprises. Previous studies have already tried to establish why, with barriers such as cost, technical limitations and performance issues and bulky hardware are seen as the barriers holding back XR from being widely adopted. With the help of a literature review containing 45 different sources the author identifies six categories each when it comes to factors that drive individuals to adopt XR technology. For the individuals these categories were (1) perceived benefits of XR technology; (2) perceived risks of XR technology; (3) individual differences; (4) manufacturer-related variables; (5) psychological variables; and (6) situational variables.

Within (1) perceived benefits, subcategories were also identified by the author (Chuach, 2019). These were utilitarian, hedonic, social, fashion, and media-related benefits. Utilitarian benefits refers to the advantages that a new technology, in this case XR, can have on one's life. These advantages can range from improving efficiency and simplifying tasks. These advantages are very individual to the user. The hedonic benefits are related to the enjoyment and pleasure one can receive from XR. It can be used as an escape from daily life and routines by playing games for example. Social benefits relate to enhancing relationships and being able to connect with others and seeing an opportunity to meet new people. Fashion benefits refer to impressing others with one's tech-savviness and fashion sense. Lastly, the media-related benefit focuses on the immersive experiences that XR can offer, and being able to deeply be involved and experience the technology.

(2) Perceived risks of XR technology is the second barrier for individuals' adoption (Chuach, 2019). Within this category there are the main factors of risk: psychological, uncertainty and physical. Psychological risk relates to the fact that using a poorly optimized or performing XR product can lead to distributing one's peace of mind. One example brought up by the

author is misusing VR applications, such as therapy, which could instead harm the users well-being. Uncertainty risk involves concerns about cost, time loss and the product not living up to one's expectation. This can lead to users feeling the product wasn't worth their money invested or time. Lastly, physical risk refers to the potential of injury caused by using XR technology. There, the author explains that VR glasses may make one unaware of their surroundings, thus increasing the risk of bumping into furniture or falling.

Individual differences (3) are the third barrier being recognized by the author (Chuach, 2019). Different factors within this category include openness to experience, conscientiousness, extraversion, agreeableness, neuroticism and lastly experience and habit. Openness to experience relates to a person's willingness to creativity and exploring new ideas. Conscientious people are organized, disciplined and goal-oriented and these people are more likely to be aware of what XR technology can offer them and how it can benefit them. Extraversion is related to optimism and a desire for stimulation. These people enjoy interacting and forming relationships with other people. Agreeableness represents sympathy, kindness and trustworthiness. These people tend to accept social invitations from their friends, however this does not mean they will remain with the product or service. Neuroticism relates to emotional stability and one's ability to confront emotions such as anxiety, anger and depression. These people may decline adoption if they feel it exerts control of their lives. Their adoption may also be influenced by perceptive popularity by their peers. Demographics is one of the factors that is most studied in relation to XR. However, the findings have been very mixed where some state that age influences more, and some state that gender has a bigger influence. The last factor mentioned by the author is experience and habit. Familiarity with XR influences how people categorize and perceive it, and may increase the adoption process.

Manufacturer-related variables (4) is the fourth barrier recognized for adoption of XR (Chuach, 2019). The first factor within this barrier is brand attitude. This represents the attitude one has towards a specific brand, making them more or even less encouraged to adapt to their XR product. Apple users who are happy with their products may be more positive towards adopting their product if they decide to enter the XR market. Price value is the other factor that has been recognized as one crucial factor when it comes to people's adoption to new technologies. When the benefits outweigh the price, people will consider it positiver, however the price to benefit value is very individual.

The fifth barrier is psychological variables (5) and relates to social norms and influences (Chuach, 2019). In the case of adoption of new technologies it refers to the influence of other people such as families and friends. These social norms can be described as either injunctive or descriptive. Injunctive are based on the perception of whether a behavior or use will be approved or rejected. Descriptive instead focuses on observing whether other people behave or use specific technologies. The last barrier is situational variables (6). The main factor within this barrier is facilitating conditions. This refers to the resources and support available to be able to adopt a technology. A perceived lack of available support and resources is seen as a barrier for users when it comes to adoption.

According to Berglund (2022) the demand for technologies that minimize equipment requirements has surged as a result of the pandemic, enabling experts to remotely detect and resolve production issues, thus increasing productivity. However, the integration of XR technologies varies in terms of maturity level, presenting clear opportunities and challenges. While XR provides opportunities for immersive learning, upskilling, and renewal, uncertainties regarding its benefits still exist. Consequently, the implementation of XR technologies remains irregular among companies, often limited to internal experimentation rather than widespread adoption. Many companies lack a comprehensive understanding of the transformative potential of XR and its impact on various use cases. As experience and testing with XR technologies grow, the possibilities and requirements for successful decision-making are starting to emerge. Therefore, it is essential to comprehend the adoption of learning and the value drivers within industrial settings. This understanding not only enhances contextual knowledge but also expands into new academic domains, ultimately motivating implementation initiatives.

Berglund (2022) aims to address the challenges of adopting extended reality (XR) technologies by leveraging authentic educational scenarios that align with industry needs. The research highlights the importance of establishing a synergistic relationship between functional learning environments and individual learners to enable educational scalability. It also introduces onboarding programs, which demonstrate specific features that enhance users' attention and facilitate a seamless adoption process. From an educational perspective, the lessons learned from XR use cases are invaluable. These experiences have the potential to disrupt traditional practices, remove adoption barriers, and enhance the transformative power

of XR technologies. A structured process is proposed to support existing users and new adopters, emphasizing the need for guidance and a self-directed learning approach that fosters interaction value. Further research is essential to deepen the understanding of how use cases and levels of engagement can contribute to a strategy that promotes tolerance for failure, tolerance for design exploration, and tolerance for efficiency. This ongoing research will contribute to building a more comprehensive body of knowledge in the field, ultimately supporting the successful adoption and integration of XR technologies. By this research, Berglund (2022) aims to identify distinct value indicators that can facilitate the onboarding of industry professionals in acquiring new XR skills. By bridging the gap between academia and industry, this research seeks to enhance academic understanding and apply it effectively in industrial settings, thereby refining skills and encouraging the implementation of XR technologies.

3. Theoretical framework

As XR continues to evolve rapidly, understanding the opportunities and challenges faced by early stage XR businesses and professionals becomes crucial. To comprehensively analyze this landscape, the application of Disruptive Innovation Theory and Adoption Curve Theory combined proves applicable. By combining the theories, a comprehensive analysis of the opportunities and challenges in XR emerges. The disruptive nature of XR, as revealed through disruptive innovation lenses, helps us identify emerging markets, potential competitive threats, and areas for radical transformation. Simultaneously, the adoption curve perspective enables us to understand the dynamics of XR adoption, the motivations of different adopter segments, and the challenges faced at each stage. Integrating these theories provides a holistic understanding of the XR landscape, allowing us to anticipate opportunities and address challenges effectively. The study is also deductive, meaning the study is building on existing theories (Bryman, 2016).

3.1 Disruptive innovation theory

The Disruptive innovation theory, firstly introduced by Joseph Bower and Clay Christensen in 1995, has since been a powerful tool of thinking when it comes to innovation driven

growth (Christensen et. al., 2013). The theory details how new technologies or companies can disrupt established markets which changes the way products and services are delivered to the customers. The term "disruptive" in the case of this theory refers to a process where businesses challenge more established businesses by high technological newness and new ways to achieve new customer demands. These already established businesses often focus on improving their existing products and services in their market based on customer demand, which may result in overlooking certain segments (Christensen et al., 2013). This is where new entrepreneurial companies can demonstrate their disruptive potential. New entrants are able to target previously overlooked segments, gain a foothold, and deliver new products or services at a lower cost compared to the more established ones who may not respond as effectively and swiftly as needed. Gradually they can move upmarket by delivering high-quality products or services that the competitors' customers require while still retaining the factors that led to their success. Disruption occurs when customers begin to switch to the products and services offered by the entrepreneurial companies, at a higher volume and speed.

The theory of Disruptive Innovation has a wide range of applications for the XR industry topic, including exploring potential disruptive innovations within the market (Christensen et al., 2013). It is particularly useful for examining how businesses are leveraging new technologies to create unique experiences and whether these startups are disrupting existing technologies or developing entirely new ones. It also enables researchers to assess whether these technologies are disrupting traditional business practices and models that have long been established in the industry, and how businesses utilize new revenue streams and channels to reach new customers. In conjunction with disruptive innovations, Christensen et al. (2013) also discuss sustaining innovations, as incremental improvements to already existing products or services. Furthermore, the theory can be applied to analyze the structure of the industry, examining how the emergence of new XR businesses is changing the industry and whether these companies are seeking to displace traditional actors. By analyzing these factors, researchers can gain a better understanding of how the industry is evolving, where it's moving and identify opportunities for growth and innovation within the XR market. This theory is especially crucial when it comes to analyzing the key drivers of growth within the industry, as well as consumer demand in relation to new technologies.
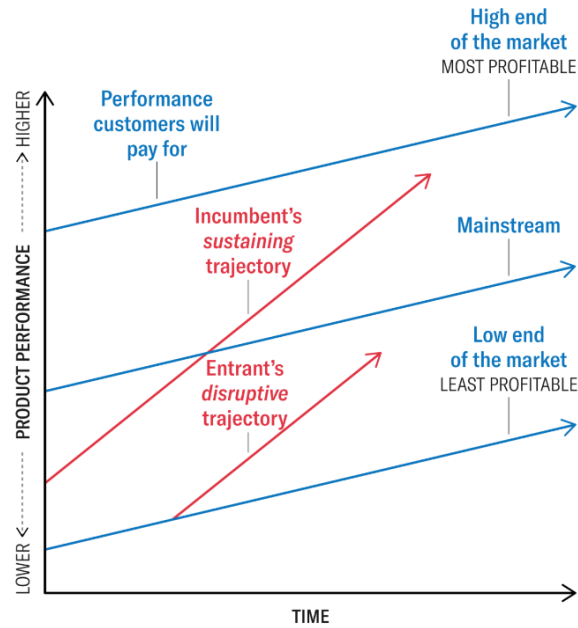
Figure 1: Disruptive innovation (Christensen 2013)

3.2 Adoption curve theory

The Adoption curve theory, also known as the Diffusion of innovation theory, helps with explaining how new ideas, products, services or technologies are adopted by a population over time. This theory, founded by E.M Rogers (2003), suggests that the adoption process follows a pattern which is categorized by five different categories of users or adopters. These different categories are innovators, early adopter, early majority, late majority and lastly laggards (see Figure 2). The first group is the innovators, who are known for taking risks and possessing considerable knowledge about the subject (Rogers, 2003). They are typically the first to adopt new ideas, services, or technologies. The second group is the early adopters, who are often opinion leaders and have a high social status. The third group is the early majority, who tend to adopt an idea after a significant portion of the population has already done so. They are usually more cautious and less willing to take risks. The fourth group is the late majority, who adopt the idea, service or technology after the majority of the population has already done so. They tend to be skeptical of changes and require evidence before committing to the adoption. Finally, there are the laggards, who are the last to adopt new ideas, services, or technologies. They are highly resistant to change and may wait until it has already become obsolete before considering adoption. By understanding the different stages of the innovation adoption curve, businesses can tailor their marketing and adoption

strategies to target each group effectively. This process is driven by communication and persuasion, mostly from the innovators and early adopters who use their influence to persuade others to adopt the new products, ideas, services or technologies (Rogers, 2003). As previously stated, the early and late majority needs social proof and evidence to be influenced into adopting, while the laggards are the most difficult group and might never adopt at all. This theory may help to identify different types of adopters of the XR technology. By identifying these different types of adopters it may be possible to gain insight into the different challenges and opportunities.

In addition to Adoption curve theory, another valuable framework to consider when studying the opportunities and challenges of XR is Gartner's hype cycle. While the adoption curve theory is more focused on the behavior and characteristics of adopters, Gartner's hype cycle is more focused on the perception and expectations of a technology, (Fenn & Raskino, 1995). Despite their differences, both models can be useful in understanding the adoption of new technologies by consumers and businesses as well as predicting their future trajectory (see Figure 2). The Hype cycle provides a graphical representation of the maturity, adoption and expectations of emerging technologies over time and illustrates the typical patterns of hype, disillusionment and eventual productivity associated with new technologies. The early stages of the hype cycle correspond to the early stages of the adoption curve followed by that the trough of disillusionment corresponds to the early majority and late majority, while the slope of enlightenment corresponds to the late majority and laggard stages. This theory is crucial when it comes to studying the barriers to entry and growth for the early stage XR businesses.
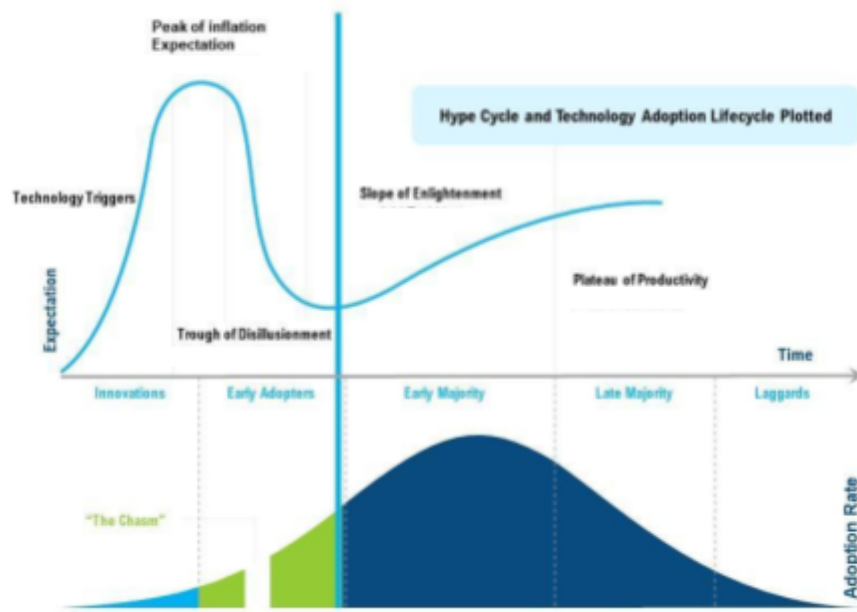
Figure 2: Gartner Hype Cycle with Technology Adoption Cycle (Slideteam, n.d.)

4. Research methodology

The aim of this study is to conduct a thorough analysis of the current opportunities and challenges presented for the early stage businesses within the XR industry. To achieve this, an exploratory and qualitative research design has been adopted (Bryman, 2016). The research methodology involves the collection of data from observations of early stage XR businesses. Observations offer a unique perspective to study the businesses. By directly participating in meetings, a contextual understanding of the dynamics and decision-making processes within XR companies can be gained. This real-time assessment provides valuable insights that may not be fully captured through secondary sources alone. To strengthen the study and add more perspectives, interviews are made with experts from the industry and academia who have specialized knowledge in the field of XR. Using multiple methods of data sources aims to develop a comprehensive understanding of the phenomena (Sherrod, 2006). Within this qualitative research strategy this could also test validity through the convergence of information from different sources. By adopting an exploratory and qualitative research design, this study can uncover insights that may not have been previously considered, leading to a more nuanced understanding of the XR industry. The advantage of using this

methodology instead of doing only a literature study is that we get direct access to early stage businesses and can therefore gather first-hand information, including what may not be widely known or documented in existing literature. Interviewees could expand these findings, either by confirming results or showing something different.

The research design is structured based on a thematic analysis, a qualitative method for analyzing data with preconceived themes expected to be found (Bryman, 2016). Thematic analysis involves studying the data and looking for patterns in the meaning of the data to find themes, which is an active process of reflexivity in which the researcher's subjective experience is at the center or making sense of the data. The methodology is particularly useful for exploring complex social phenomena by analyzing systematically obtained data, and involves a 5 or six step process: 1) familiarization with the data, 2) coding the data, 3) generating initial themes, 4) reviewing and developing themes, 5) refining, defining and naming themes, and 6) reporting (Alhojailan & Ibrahim, 2012).

In the first stages, the researcher gets familiar with the data collected (Alhojailan & Ibrahim, 2012). Data is broken down and assigned different codes, which are then grouped together into categories and themes. When reviewing and developing these themes the researcher finds connections, similarities and differences between the data. In the final stages, themes are defined and presented. In this thesis, the collected data is coded and put into mindmaps to enable the researchers to work effectively together, visualizing the information and brainstorming while following the process. The data collected is mapped out, coded and categorized according to different themes found during the study. In conclusion, this methodology provides a comprehensive framework for exploring the current opportunities, and challenges of XR technology through observation of meetings and interviews with professionals in the field. By following this methodology, the researcher is able to gather valuable insights.

4.1 Observation of XR businesses

Research settings and participants

To get in contact with early stage XR businesses, we were invited to attend and observe meetings between early stage XR businesses and ImmersiveUnity where the businesses were pitching their ideas and potential funding and collaboration (ImmersiveUnity, 2023). The network has a community of 70000 XR developers located in 70 countries, to whom they are offering XR development services, and investing in the industry. The observations were systematic based on a predefined observation schedule as they were carried out during already pre-scheduled meetings via Zoom. Each meeting included representatives of the network and one early stage XR business. Representatives from the businesses were founders and one to two additional managers, while representatives from the network were the Chief Executive Officer (CEO), Chief Innovation Officer (CIO), Chief of Investor Relations (CIR), Chief Operations Officer (COO) and XR Startup Evaluator.

The observations were conducted between 2nd of March to 16th of March 2023, from 4 to 10 pm. The amount and selection of companies are based on a convenient sampling method, as we select participants who are easily accessible and readily available to participate in the study. The total number of meetings are 26, meaning there are 26 businesses participating in the study. Of the 26 XR businesses most of them are working with metaverse platforms, events & entertainment, software products and gaming. Almost half of the businesses, 12 of 26, worked both with VR and AR, while 12 worked only with VR and two worked only with AR. 7 of the businesses are pre-seed, 15 are seed and 4 are series A. One of the companies is registered in India, one in South Africa, one in Canada, seven in the United States, four in United Kingdom and the rest in European countries.

Number of businesses	Industry segment
5	metaverse platforms
5	events and entertainment
4	software products
4	gaming
3	education and job training
2	sports and workouts
2	fashion retail
1	healthcare

Table 1: Overview of companies observed

The sample of businesses can be seen as representative as it has variation in terms of technology (VR, AR or MR), company size (number of employees), XR category (health, metaverse, entertainment, retail etc), location (North America, Africa, Europe, Asia etc.) and stage of early funding. The stages of early funding is either 1) pre-seed, meaning that their goal is to demonstrate that their product fulfills a market need, 2) seed, which means that their purpose is to prove their product market fit or 3) series A, which is the next round after seed funding when they are aiming for scaling (SVSG, n.d). As these meetings usually are not open for the public, we as researchers get an exclusive opportunity to study some of the XR businesses more closely. Some of the companies have paying customers, but some have yet not launched their products, which gives us real insight into the opportunities and challenges these businesses are facing.

The meetings themselves are for XR companies pitching and discussing their products and services in front of representatives of the XR network. Depending on what the company is searching for, a decision will be taken during the meeting and result in investment, partnership or a sales commission based agreement. All of the companies have had a previous meeting with the representatives of the XR developer network, more focused towards pitching their business idea and visions, whereas this second meeting is towards possible cooperation or funding. Timewise, the meetings consist of 15-30 minutes of pitching their business, idea and vision, followed by 30-45 minutes of decision making. The majority of the meetings take one hour, including questions and answers (Q&A) with the representatives and businesses. Before the meetings, data is shared with researchers including information about each company including stage, industry, contact information, website link, location and business model, as well as a one-page description pdf, their pitch deck and an optional pdf with more information about their company and product. This information provides a context and pre-understanding of the companies and for the researchers, as it is the first time meeting them. In the beginning of each meeting, all of the participants are presented by the CEO of the network, including representatives of ImmersiveUnity, representatives of the XR business, us researchers and the study. Despite the set agenda and limited time, there is an opportunity for the researchers to additionally ask 1-2 questions to each company. The questions are asked in the very end of the meeting, as neutral open-ended questions:

- What opportunities are you currently facing in the XR industry?

- What challenges are you currently facing in the XR industry?

The reasoning behind these questions were firstly due to the time limit as we were only allowed a short time at the end of the meetings, so questioning the businesses directly about their opportunities and challenges were of most importance. Our questions were primarily focused on opportunities and challenges with XR. By asking open-ended questions we received a lot of answers focusing on both the technology of XR itself and also how the industry is shaping up, as well as how the different businesses see it moving into the future. Secondly, by asking 26 different businesses about their experiences in the XR industry also allowed us to identify common trends and outliers through their answers.

Data collection and analysis

Data collection is conducted through observation of meetings with XR businesses on Zoom. While one of the researchers asked the questions, the other one took notes. This responsibility is altered for variation. As the observations including the questions, are not allowed to be recorded, no transcription is done. Instead, the answers of the question and additional notes are taken by both researchers during the observations in an Excel sheet. To be able to categorize the information, some key words are used such as company name, category, industry, unique selling point (USP), what problem they are solving with what solution (see Appendix A Observations of XR businesses). Also, the two main questions are asked and noted.

Thematic analysis with open coding is used to analyze the collected data from the observations. This involves identifying common themes across the data and categorizing them into relevant topics. The themes are analyzed to identify opportunities, and challenges in the XR market. The data is read with the aim of gaining a sense of understanding of the greater perspective. Thereafter it is broken down into units and smaller notes in order to sort the data into different themes by coding. The data that is not fundamental is reduced, to create a valuable presentation of the chosen material. The different codes found are categorized and placed into different themes related to Opportunities and Challenges.These themes were identified as Technology & Development, Business & Industry, Staff & Recruitment, Users & Adoption, Financing. For challenges one extra category was created, Inclusion & Diversity, since this was not brought up as an opportunity. Within these categories, there were different

codes and narratives, which all together became mindmaps, summarized in a table in Results (see 5.1 Observations of XR businesses). These themes cover technological advancements, market dynamics, workforce needs, user acceptance, financial aspects, and ethical considerations. Understanding these themes is essential for informed decision-making and fostering sustainable growth in the XR industry. In summary, each theme contributes to valuable insights and together cover a holistic picture of the study of opportunities and challenges experienced by XR businesses.

4.2 Semi-structured interviews XR professionals

Research settings and participants

Five interviewees are selected for the study, found by using personal contacts in the field of XR that have been able to recommend following participants. This way of selecting participants is based on a snowball sampling, which begins with a convenience sample of one or more initial participants (Emerson, 2015). In our case, one of the interviewees gave us tips regarding people connected to the XR industry that would be relevant to contact for our study. The participants' backgrounds range from academia to industry and there is some variation in gender and age. All of them are active within the geographical area of The Øresund Region: Copenhagen, Malmö and Lund.

The interviews take approximately 40 minutes and are conducted on Zoom during the time frame 6/3-17/3. Conducting the study on Zoom enabled us to record the interviews in a more efficient way and to be more flexible towards our interviewees. The interviews are semi-structured, which is an effective method for data collection when the researcher wants to collect qualitative open-ended data and to explore participant's thoughts, feelings and beliefs about the chosen topic (Blandford, 2013). The format also helps to delve deeper into sometimes personal experiences and encourages two-way communication, which is what we are aiming at.

As the interview is semi-structured, some of the themes and questions are predetermined, containing neutral and mostly open-ended questions. The following themes cover the areas of

interest related to the study: Technology & development, Business & industry and, Social & ethical. Similarly to the themes in the observation of the XR businesses, these contribute to the understanding of the experiences of XR businesses when it comes to opportunities and challenges.

The interview guide is accessible in the appendix (see Appendix A Interviews with XR professionals). The questions are aimed towards understanding the XR professionals' insights of working and researching in the field, investigating potential opportunities and challenges they encounter within the industry. The interviews contribute to answering the research question, by adding depth and value to the study from other XR professionals than the business founders only.

Data collection and analysis

To collect the data, the interviews are recorded on Zoom. While one of the researchers acts as the interviewer, the other researcher is in charge of taking most of the notes during the interviews. To process and analyze the collected data from the interviews, thematic analysis is applied. The collected data is processed by dividing the data in a three step process. First, the data is recorded on Zoom and transcribed with help of a dictation function in Microsoft Word. Secondly, the data is read with the aim of gaining a sense of understanding of the greater perspective. Thirdly, the material is broken down into paragraph units in order to sort the data into codes related to the different themes of the interview: Technology & development, Business & industry and Social & ethical. Within these categories there were different codes and narratives which all together became mindmaps, summarized in a table in Results (see 5.2 Interviews with XR professionals).

4.3 Critical reflections

Ethical considerations

When conducting the study there are several ethical considerations to include. This was something discussed in the initial communication with the contact persons. Due to the restricted information of the XR businesses within the network, a non-disclosure agreement

(NDA) contract is signed in the early beginning of the study with ImmersiveUnity to confirm confidentiality.

It is important to obtain informed consent from all participants before conducting interviews and observations (Wiles et. al., 2008). This means providing participants with a clear explanation of the study's purpose, procedures, potential risks, and benefits, as well as ensuring that they have the right to refuse or withdraw from the study at any time. In this study, informed consent is made with the participants before the study, in written form on mail and in the beginning of every observation respective interview, orally.

To ensure anonymity and confidentiality (Wiles et. al., 2008), participants were informed that their identity and personal information will be kept confidential and that their responses will be reported in aggregate or with pseudonyms to protect their privacy. When describing the companies, it is only told how many operate in each sector and segment. The interviewees got randomized pseudonyms from a list with popular unisex names (Nonbinarywiki, 2023), every 5th letter from A to Z: Alex, Fay, Kim, Percy and Uanie. We aimed to open up for questions and let the participants know they can reach out afterwards if necessary.

Limitations

Acknowledging the ethical considerations, the limitations of the study and potential sources of bias in the analysis increases awareness and striving for objectivity (Price, 2004). We therefore try to be as transparent as possible, by motivating different decisions and acknowledging bias. The researcher's own biases and perspectives may influence the study in terms of the interpretation of data and conclusions drawn (Elston, 2021a). Therefore it is important to acknowledge and address these limitations in order to accurately interpret and apply the findings of the study. It may be complimentary with additional research methods or to conduct follow-up studies to address some of these limitations.

The aim of the study is to explore the opportunities and challenges faced by early stage XR businesses during spring 2023, which is in the period when the thesis is conducted. Although the XR industry is characterized by a dynamic nature, the study can give a representative picture of how the industry looks like during that time period, and provide valuable insights

By acknowledging the potential for future changes and limitations of the study, researchers and readers can use the study as a baseline for comparison and to inform future research.

Regarding geographical limitations, through ImmersiveUnity we get access to an international network of XR developers, spread out in different countries and continents. Although there is variation, the businesses are not represented from all continents (Oceania and South America), and may only be located in specific geographic areas. As we are addressing the industry globally this becomes an issue, as the study might be affected by a eurocentric perspective. When it comes to the semi-structured interviews, as they are found through contacts within the Oresund region, it also may limit the generalizability of the findings.

It is important to remember that a small sample size may not be large enough to draw conclusions that can be generalized to the broader population (Elston, 2021a). Even though the XR businesses with their technologies have a strong variation amongst them, the selection bias of the 26 companies may not be representative of the broader population of early stage startups. By clearly defining the study population and the sampling technique as well as being aware of bias, we can aim for avoiding it. There is no self-selection bias in the observations, as all the companies that are having meetings with the XR network are willing to participate in the study. However, according to the Hawthorne effect (Elston, 2021b), participants may modify their behavior or responses because they know they are observed which could affect the validity of the data. We are therefore aware of the fact that their responses can be influenced by the interest in the topic or potential benefits, which is of high chance also because the business representatives are entrepreneurs and naturally interested in the topic of their business and industry.

Although the collaboration with the XR network enables us to conduct the study and get access to very exclusive material there are some limitations due to the signed NDA contract. These limitations include that we are not allowed to state specifically the idea that the companies are developing. This means that we need to adapt the study and instead look into more general trends regarding the challenges and opportunities they face, or refer to a company as in what industry category it belongs to.

5. Results

Followingly the result will be presented in two sections. First, the observations of the XR businesses with opportunities and challenges that will be presented separately in table format with further explanation. Secondly, interviews are presented in table format and text together with direct quotes of the XR professionals.

5.1 Observation of XR businesses

Opportunities

Themes	Categories	Open Codes
Technology and development	Tech advancements	- Create sustainable solutions - Minimize costs - Leading the market, offer more devices - Build tech compelling enough - Can be more effective, pedagogical - AI generative tools for content creation/moderation/detection
	Increase creativity	- More creativity - Creating seamless experiences - Merging media and content - Integrating design, art, culture - AI generative tools for content creation/moderation/detection - Increase positive behaviors and awareness
	Building communities	- Virtual avatars and identities - Create virtual fan bases - Leverage unique audiences - Create relationships with users - Behavioral evolution - Building communities - Unite humanity - Sharing possibilities (data)
Business and industry	New industry	- New industry - new possibilities - Technological advancements - Increased market demand - New and unexplored markets - Innovation, collaboration and economic impact

		- Little competition
	Synergies	- Synergies and potential for collaboration - XR will not completely replace other media, - Advantages and disadvantages with every technology/media
	Accessibility	- AR seems more accessible than VR - AR glasses might soon be released
Staff and recruitment	Core team	- A core team is needed: highly valued education, experiences, skills and contacts - If less resources, bring in interns or part timers
Users and adoption	Adoption	- Slow market penetration → saves time - Important with support and mentorship to learn → Integrate it into the service
	Transparency	- Transparency → helps creation and modification - Increases user satisfaction, relationship
	User generated content	- More user generated content - Let stakeholders be part of the XR experience and development - Connect to the younger generation - Let users build together with the XR platforms/metverses
Financing	Income sources	- Collaboration with partners, brands, sponsors for PR and income - Lowballing - Backed up by R&D means income and fair pace of development
	Currencies	- Using crypto currencies

Table 2: Opportunities of XR businesses

Technology and development

There are many opportunities, although the businesses state that it is currently a challenging market. The businesses that feel more secure, which could also be seen as an opportunity, are the ones that offer more devices or software in comparison with their competitors. A company building tech for 100% of the market states that they are wanting and planning to start acquiring the rights and becoming a market leader to first capture and maintain the status. Another one also mentioned that some companies "die" fast because they are too quick with building something that is not compelling enough, which is important to know when entering the market. A technology and tool that businesses bring up several times by

many of the different businesses are AI generative tools such as ChatGPT, as an opportunity, which can be used for various reasons such as creating content for new virtual worlds and realities. It can also serve as a moderating and detecting tool.

Among opportunities related to technology, the businesses bring up much around the many possibilities and benefits XR has. It can help minimize costs and be a sustainable solution and alternative to traditional methods by its opportunities of remote experiences, accessing information in a new alternative way and offer these experiences to a larger extent accessible for more people. One of the businesses uses XR to create immersive experiences that allow people to understand and appreciate nature and wildlife, without disturbing them and causing any harm, by letting them be surrounded by nature and animals in XR. Similarly, XR could be used to simulate environmental disasters, pandemics and wars without having to experience it in real life. This can help raise awareness about global issues and inspire people to take action.

Another business uses XR to create more specific and immersive scenarios, which enables bigger groups being in the virtual world at the same time. Their business helps industrial workers during training by making it more safer, trying out different work tasks beforehand in a safe environment as well as in a more pedagogical way by integrating moments that are not possible to do in the real environment. The more traditional classrooms and teaching methods in this case may become less effective as XR technology advances and enables students to have immersive and interactive learning experiences remotely, in a more effective, safe and cost-saving way.

Apart from lowering costs and becoming a more sustainable option, XR technology with its metaverse platforms has the opportunities of bringing people together. One of the sports- and workout companies brings up an example of a workout at home or at a gym that can be seen as boring, slow and sometimes expensive. It is now possible to do so much more creatively in XR, which could possibly increase people's motivation to work out. Working out in different environments, with different people (friends, professional instructors, celebrities etc) from a person's living room means infinite extended gym experiences, all of this in XR creates endless opportunities for businesses. Some of the companies within the creative industries such as culture, art and fashion, bring up the many opportunities they see when it comes to integrating more design and creating relationships with fanbases in XR. They bring up the

importance of creating seamless experiences, such as shopping experiences, with fashionable design of the metaverse, which according to them also will increase the attractiveness of XR. There are endless opportunities on how people will look and act in metaverses where people can have avatars and different identities. These companies mention that, as in real life, design matters and reflects who you are in the metaverse and how many endless opportunities there are for people to express themselves and explore.

According to these businesses, not only creative industries can benefit from the design attraction and creating stronger relationships with fan bases through celebrities and influencers. It can leverage a unique audience and create a growing customer base. The biggest strength then is not only being a XR company, but also having a customer base that can set you apart against competitors. The companies bring up how it is important to build a company reflecting a brand, a character and personality - creating a relationship with the users as if they are friends. Brands need to cultivate the next generation of buyers. In this case, the fashion and retail company is selling high end products, luxury products within art, fashion, sport and entertainment with partnerships with famous artists and sports players. These companies want to create a relationship with the users, and therefore customers need to spend time with the brands. According to one of these companies, it will create a big behavioral evolution, eventually a trillion dollar market.

Many companies, especially the metaverse businesses are building platforms for users focusing on building communities. This, to create a sense of belonging, a safe space, a family, mutual understanding. As XR has a lot of opportunities, it is a wide ocean free to be explored and can be used to unite humanity. One of them mentioned that this can even bring humanity back to the agora era in terms of democracy, market and civilization. Another aspect of the opportunities of creating a big customer base and sharing community is the possibility to gather the audience around certain things. Also the opportunities increase when it comes to collecting large amounts of data, such as geolocations and demographic data.

Business and industry

The opportunities are many due to XR being a new industry, and therefore not as explored as older industries. There are technological advancements, increased market demand, new and unexplored markets, an environment of innovation, collaboration, and the potential for significant economic impact. According to the businesses, entrepreneurs and companies that

recognize and capitalize on these opportunities can establish themselves as leaders in the industry and shape its future trajectory.

According to the participants there's a higher chance of creating a product or service that would succeed when there are fewer businesses on the market as it creates less competition. Many of the participants say that there is a possibility to take advantage of the many synergies there are between XR startups, which some are very positive about. Synergies both in terms of similar businesses and organization but also in terms of technology.

Something mentioned by several participants is that although new media often replaces old media, they do not see that different media forms within XR will not completely replace others but will live side by side for a long time. Web 3 will not completely replace web2. AR is not replacing VR. Each tool has its own advantages and disadvantages. Also, although there will be digital and virtual experiences available and maybe taking over much of the physical alternatives. The businesses are certain that there will be continued physical experiences. Society is being digitized and moving towards more XR, where 2D data is being converted into 3D data. Something businesses bring up during many discussions is the comparison between AR and VR, where most of them see AR as more accessible than VR. More people have a smartphone than a VR headset. This is something that many companies and industries have understood, and therefore mostly focus on AR.

Staff and recruitment

The main opportunities mentioned by all of the businesses regarding staff and recruitment is to have a well working core team; key people with highly valued education, experiences, skills and contacts. Many of the founders of the businesses started alone or with one other person for a long time. One of the opportunities faced by the businesses is also to expand the team by taking in part-timers and interns, without raising much costs.

Users and adoption

Businesses bring up the question they have been confronted by: "How are you actually gonna meet the demands if they evolve?". It is a challenging question for them, especially if the demand is higher than what one can offer. However, thanks to the speed of market penetration, businesses can be saved timewise by the fact that the rest of the world is adapting to XR technology slowly. One can already sell products and services to the market, while

continuing to simultaneously develop the technology. One business focused in art and education mentions the need for support when using the tool or platform in XR. How do you know if you are learning it correctly? There are also different ways of using it correctly, and therefore another question brought up is how to learn using it artistically? In their case, to learn the artform they mention mentorship as something that the users will need, and therefore is something they provide. This is something that many businesses and users don't think about, according to them.

Many of the businesses, for example the ones creating games or metaworlds also mention transparency, letting the users know that it is under "construction" or in its early stages and that the users are also important for the creation and modification of the products. This creates great reception among users and a positive willingness to try out the products and give feedback to the business. Same goes for user generated content on different XR platforms, as businesses mention that users can all benefit from being a part of the experience.

Some businesses focused on games and metaverses bring up the importance of connecting to the younger generation, as they are the ones who will constitute the largest customer segment in the future. Many people, especially of the younger generation, are very interested in creating, programming and building themselves - either in personal websites for blogging or when it comes to building worlds and cities etc in games like Minecraft and Roblox. As many aspects of XR, such as creating worlds of metaverses, includes programming and creation, there are many opportunities of connecting to them. Even better is to let users take part and create themselves, which some of the businesses are taking advantage of and incorporating into their business model.

Financing

There are several financing opportunities for businesses. A good way to get income as well as PR is to collaborate with partners, sponsors and well known brands. Key technical and commercial relationships can create good money streams, and benefit both parts - how to make (big) money together. Some companies are partly funded by Meta themselves, or other big brands, and some are lowballing for big opportunities. The companies being backed up financially by Research and Development (R&D) have another kind of security. Both funding-wise, but also timewise as the pace of research determines the pace of the businesses.

An opportunity mentioned by many of the businesses focused on metaverse and different platforms is crypto-tokenization and tokenomics as something that both includes risks but also a lot of opportunities. There are already platforms and metaverses using crypto currencies and other tokens, and this could increase in XR, if more decides to follow this development. Some of the opportunities are increased engagement, new revenue streams and decentralized marketplaces.

Challenges

Themes	Categories	Open Codes
Technology and development	Content	- Limited content/non-democratic content
	Tech	- Challenging but important to create something that works on different devices - Incorporate 5G into XR for improved connection and stability
	Hardware	- Good hardware is missing but might be on its way
Business and industry	Competition	- Hard to compete against big players, Meta - Hard to get support from big players or even pitch an idea to them - Who is a competitor or collaborator?
	Hype	- Hype that starts to decrease - The VR market is not established enough due to previous content and technological issues - Hard raising funding with less attention and less consumers
	Ethical issues	- Ethical issues about what markets to enter, military or violence related
Staff and recruitment	Competition	- Strict budgets of startups - Competition with the big players on talent attraction and salary competitiveness
Users and adoption	Adoption	- User adaptability and acceptance - Onboarding, accessibility and training is needed - Not adapting the technology to all - Create a user base that stays (persistent)
	Creativity	- Lack of imagination

Financing	Investment	- Yet not stable market - Hard to find investors (tech skepticism) - Investment issues due to post covid and inflation - Disappearing hype - less investments - Political changes and geographical differences, e.g post Brexit
	Transparency	- Shared agendas (and profit) when collaborating with partners - Transparency when showing who is funding the project or product
	Currencies	- Risks with crypto currencies
Inclusion and diversity	Exclusion	- Discrimination - Homogenous industry (white male dominated) - No contacts or belonging in the "in group" makes it very hard to get support, funding etc. - Different stakeholders want to control/shape founders/entrepreneurs in a negative way
	Risks for XR	- Lack of diversity and inclusion in industry and technology - Risks of using biased data

Table 3: Challenges of XR businesses

Technology and development

Many of the businesses who produce content mention that content is still very limited, and also non-democratic. With saying that the content is very limited, some businesses drew comparisons with the amount of applications you can download on your phone through the appstore for example. They mentioned that while there are applications able to download from the Oculus store for example, the amount of applications and the topics they cover are nowhere close to other mediums, and is thus seen as limited.

Many businesses mentioned that a technical challenge is that good hardware is still missing such as more comfortable headsets for VR, and glasses for AR. However, new and improved AR glasses are rumored to be on its way. According to some of the businesses, the wide range of devices makes it challenging but important to create a technology that works for different devices. Examples are technology that works both for different operating systems such as Android and iOS, or for the same operating system but for old and new devices or versions. Another challenge mentioned, that could also lead to an opportunity, is to

incorporate 5G bandwidth into the existing XR infrastructure. This would result in being able to connect more devices as well as improving the stability in crowded areas.

Business and Industry

There are struggles within the XR ecosystem when it comes to who is leading and paving the way. Meta is the biggest player on the market, as they do a lot on VR and AR. Some businesses mention that a lot of content creators have a hard time trying to get on the Meta platform or get their support, even when one has a great product or idea. It is all about timeliness and expanding the business, getting the market share that they want, faster. Also when it is not fully clear who is a collaborator and who is the competitor, as sometimes it is the same.

Many businesses touch upon how to keep up the hype that has started to go down. XR is a cycling market and this is not the first time the VR and AR has had a big hype. In the past the VR market did not establish itself on the market enough due to its content and technological issues. Businesses mention that this time, they have to keep this hype up with good products to avoid the same story they saw in the past. At the same time, some businesses bring up that most of the attention has currently shifted to the AI generative space. This could expand the focus and increase development of content and technology. However, one company states that there are also negative effects, and that it's going to be hard to raise funding with less attention and less consumers. In addition, in terms of strategies, businesses mention the go-to-market strategy as one of the most important and can indicate if a business is going to succeed or not.

There are also some ethical issues when it comes to what markets to enter. Most of the businesses creating platforms and metaverses could enter many different sectors and industries, and one of them is the military. Although this sector could result in big revenue streams, some are critical to it not thinking it is ethically correct. This also applies for areas where VR treatments include violence, where some businesses touch upon the difficulties in knowing what to say yes or no to, and what is defined as ethically correct.

Staff and recruitment

There are more challenges than opportunities described by businesses regarding staffing and recruiting. Mostly it depends on the strict budgets of startups. Another issue is talent

attraction, which is hard when competing with big players, such as Meta and Unity, and salary competitiveness. One of the founders of the businesses mentioned that if you want to grow, you want to have a proper team of developers, to tackle the many challenges that can occur.

Users and adoption

The XR industry is relatively new as businesses experience that it is challenging with the user adaptability and users not seeing it as a harmful technology, even for professionals working within tech. Onboarding, accessibility and training is needed with the technology. Adapt the technology for as many people as possible. Businesses that are not doing games themselves bring up the great example of gamifying things and market themselves in an artistic way, the lack of imagination is the only limit. Businesses focusing on creating platforms also state that it is important to gather users around areas of interest, and create a user base that stays persistent and wants to stay and spend longer time in the XR or metaverse.

Financing

There are many challenges within funding for XR businesses, as the market is very young, and yet not stable. Raising money and being in the right decision at the right time is the struggle for all businesses. In the first place it is hard to find investors, but when finding them there comes other challenges. According to the participants, some investors still think VR is a bubble that will burst at some point in the near future. For serious investors, it is not as easy to invest now in many places of the world due to inflation and after pandemic effects on the economy. The current economic situation for startups and particularly within the XR industry, it had a momentum that bottomed down. Therefore, one of the most important key performance indicators (KPI's) is sell through, meaning sales which reached the end customer, and measures efficiency. In the end this is what counts, according to some.

One important aspect that is up is the geographical differences, which affect the economic circumstances. Companies in the UK are affected by the changes due to Brexit when markets have crashed. Starting a company before Brexit is completely different to starting it during or after Brexit.

It is an opportunity to work with partners, sponsors, celebrities and big brands. However, apart from shared profits that can also create other challenges such as divided ideas, agendas

and shared profits. Another aspect regarding transparency is when it comes to showing or not showing who is funding the project or product? What will happen with the marketing?

Crypto-tokenization and tokenomics is talked about, both as opportunities but also as risks. Some of the risks include limited adoption, regulatory uncertainty and market volatility.

Inclusion and diversity

Sometimes it is not enough to have a great product. Something that is only discussed by one of the businesses is the fact that the industry is quite homogenous, white male-dominated. It is explained that there are different types of discrimination occurring in the industry, such as racial discrimination and gender discrimination. This occurs both when it comes to who gets the funding, but also in terms of support in other ways. Many businesses state that there are many in- and outside groups depending on contacts and relations or references. For example, it could fasten or destroy the scaling of a business. The same business representative that discussed the discrimination issue, also continued on the topic of inclusion and diversity when it comes to technology, as it has serious effects when it comes to how the data is trained. It is very important using synthetic data, to try to avoid biased data as much as possible, however this is not something all companies do.

The same person also discusses that it is challenging when it comes to what kind of founder one wants to become, as many people will try to shape you and your business. It is therefore important to pick the right people to listen to, as a lot of advice will be really wrong. Same goes for how incubators and the industry want you to be and become as a founder. For example there are investors and others that want you to do certain business actions, such as exploiting user data, which is not something that you may want. When just wanting to come up with a good business idea, this happens quite consistently.

5.2. Interviews with XR professionals

Theme	Categories	Opportunities
Technol ogy and	Advancements	- Technology develops - Devices get lighter, advanced

develop ment		- Mature technology in an immature market - XR technology gets cheaper - Effective for training repetitiveness, simulations, alternative education Testing prototype, in controlled environments - The tracking and recognition function is improved - VR is currently more established than AR - The future will have smoother AR glasses or lenses - Technology changes all the time, digital plenitude - Personalized advertisement in future lenses
	Integrating technologies	- 5G and AI can advance XR and bring new investments - Integrating XR with AI - Integrate XR into open source
	Adoption	- More people have started using it due to headsets being lighter, creating less motion sickness etc.
Busines s and industry	Hype	- Mature technology in an immature market - Continuous work in silence due to decreased hype - From excitement of XR to serious usage - The threshold is lower to try/work on X
	Digital plenitude Variation	- Used in different industries → influences other industries, areas of use - Some will use more XR technology some less, digital plenitude - Despite competition there is chance to succeed as a startup
Social and ethical	Tech for humans	- Technology is a social phenomena, human made - and will be affecting and adapted by humans (both opportunities and challenges) - people will be more dependent on digital, virtual artifacts (different resources, financial etc) - Considering different needs and accessibility of people - Can offer education to a larger extent, more sustainably and immersively - Easier to list what XR can not do, it has many opportunities - Blurring boundaries between physical and virtual identities, societies
	Using XR for value	- Important to work with XR for the value and purpose and not the technology itself - Important to look at pros and cons with XR
	Data collection	- More data for better decision-making
	Building communities	- XR could be used to benefit societies - Create boundless communities, gather, engage etc.

		Building future sustainable cities by prototyping and simulating them beforehand - Creating nicer public environments - Possibility to reach certain sustainability goals if investing more in that type of nudging
and societies, cities		- Building future sustainable cities by prototyping and simulating them beforehand - Creating nicer public environments - Possibility to reach certain sustainability goals if investing more in that type of nudging

Table 3: Opportunities of XR professionals

Theme	Categories	Challenges
Technology and development	Advancements	- Mature technology in an immature market - future challenges will be to incorporate other senses - Transportation in XR - Create less data heavy products
	Integrating technologies	- Integrating XR with AI
	Adoption	- Many who are against the technology had a bad first experience or are just skeptical - Some experience XR like stepping out of their comfort zone
Business and industry	Hype	- Mature technology in an immature market - Technology is good but forced - Lost trust of the big players in the market - The hype of XR has faded out (Gartner Hype Cycle), - Hard to convince the world to start using XR - Many don't take XR seriously still - The industry is pushing for metaverse and hypeing itself up - Customers and citizens need to engage in XR - Not be dependent on certain project funds - Not using XRs full potential → missing out on great chances
	Digital plenitude Variation	- Business interests will affect the technology → reflected in usage - Finding the right user segment
Social and ethical	Tech for humans	- Ethical issues are not being talked about enough - (Design of) XR can affect people's perception of reality - strong impact on various addictions - Humans have biological and natural limitations that need to be considered in XR - Digital segregation

		- Blurring boundaries between physical and virtual - identities, societies
	Using XR for value	- Many businesses fail with not applying XR to a real problem, goal. - Not anchoring it in the organization or using the full potential of XR
	Lack of regulations	- Lack of standardization, guidance - Peoples online behavior is critical (discrimination, violence, harassment) - Legal boundaries and human boundaries need to be set for XR(the existing ones are too low) - Unregulated platforms will be exploited - More stakeholders need to be involved when setting regulations - Important with cyber security and standards
	Data collection	- Risks with data collection (tracking etc) → individual as well as larger societal problems - Dependence on what interests are behind the collection of data.. - XR can collect much information about the surroundings, privacy - People don't care about their data tracking and sharing

Table 4: Challenges of XR professionals

Uainie is a trained engineer in computer technology, who learned to program and invest in technology, but did not work with it specifically, instead entered the industry as a founder and co-owner of a game focused company. Now, Uanie is the CEO of the company and working less with the consumer market for games and games as entertainment and instead, more with new technology such as VR and serious games applied in different segments (training, education, communication, visualization). Uanie also has close connections to the gaming industry including sitting on various boards.

Fay has experience of working with XR for more than ten years. The main role is being a researcher and teacher at a university in Sweden, teaching courses in VR and AR or assisting in various projects related to XR. On the side, Fay also has a company, developing VR and AR apps.

Kim has a background in digital culture, experimenting with different types of media and interactive installations, which gave experience in VR and AR. The focus and curiosity is not only on storytelling but also (realization of) cultural heritage. Today Kim is a lecturer in Media Technology and has contributed in publishing a book, a collection of shared experiences around AR and VR.

Alex works with job training at a global tech B2B company, offering products and services in media monitoring. Currently, the work is about developing a VR app used for educational purposes, as part of improving the company's training offering, where the VR app could assist the instructor-led training with being accessible more globally. Before 5 years in this role, Alex worked as a technology informant trainer at different companies, making use of skills in user experience (UX) and communication from having a background in interaction design and linguistics.

Percy is now working at a technology consulting company, as what he would describe as "a technical evangelist". However, the interest in XR started by coincidence around 2012 with paternal leave in combination with a VR set. Percy has since then tried a lot, for fun and for work and built things in XR, as well as had close cooperation with the university to test different aspects of VR.

Something in common for all the participants is that they have seen the development of the XR technology and industry throughout the last years, some from the very early beginning. Some work very close to the technology itself and its users, while some do mostly research. What is interesting to point out is that in the beginning when no one really knew about the XR technology and science behind it, these people within the field describe themselves that they got to teach and present for others by letting them try out the technology themselves, such as the headsets, and showing visionary images and explaining. Most of them are naturally curious and positive towards the technology, however it has been good to get familiar with it and discuss both positive and critical aspects of XR.

> *"I am very positive, and have shown things from the positive side, but after I was told about Black Mirror on Netflix, I got a wake up call - there are not only positive things about technology. You can, if you want, use XR in a negative way. That's why I make*

sure to always end lectures with some ethical questions to create a discussion around it" (Fay, interview, 2022.03.14).

"*Technology changes all the time. When I started working it was mobile phones from the eighties and now we mainly work with Oculus guest which is already so much easier. But still, it is a pretty big and limiting device*" (Uanie, interview, 2022.03.14).

The first headsets are described as very big, uncomfortable to put on and wear. The early VR also had a lot of motion delays and created a lot of motion sickness delays. All the interviewees state that these problems have decreased as the technology has developed, to be much more light, advanced and mature. Alex describes how before, there was a constant problem of traveling physical trainers and heavy equipment for their education training. In comparison, today both XR educators and different education programs are accessible in headsets and environment simulators.

Some think it's a mature technology that can be used for a lot already. However, there will still be continuous developments. Some think that it is still an immature market, where people don't seem to be convinced yet to use the technology. An immature market has low trading volumes, depressed prices and or low volatility. A mature market has reached a phase where earnings and sales grow slower than in growth and emerging markets.

Almost all, both in academia and industry, bring up the Gartner hype cycle to refer to the hype that XR had, that has faded out. For example, many thought VR would become something big but it hasn't quite taken off yet. However, it has continued in silence, beyond attention.

It is described by the interviewees that in the beginning, there is a lot within the entertainment industry with pure gamification and the excitement and "fun" of it. Now, more companies are starting to see the advantages of XR, in different industries such as manufacturing, tourism, education, and healthcare. A lot is being developed to be cheaper, better and to be used in different ways, to interact and influence other industries.

During the interview with Percy it was mentioned that XR technology can make a major difference in history class, by letting the students ''re-live'' certain events instead of reading

about them. Other instances where XR technology really could help students was in lab work. Current challenges such as lack of space, hazard activities and other risks due to distance learning could be solved by the use of XR. When it comes to training for repetitiveness and correct use XR technology has a lot of benefits also, such as simulating real scenarios. It was also mentioned during the interviews that using XR can reduce training time by 40 percent and at the same time improve employee performance up to 70 percent. This is a great opportunity for the future of education and training, as it is efficient from so many different perspectives.

Most of the interviewees mention that the main reason they work with immersive technology, XR, is not for the technology itself, but because they see another reason, a value, such as solving an issue where the tool to do so is the technology. Although the tech part is good, the real usage and need is not always found which is an important aspect. To not just create XR for the tech itself but because of solving a problem or a need, and additionally a business opportunity. "*I am inspired by different directions in different industries and to keep track of them and use it in my day to day work to drive our business and benefit from it.*" (Alex, interview, 2022.03.10) Many of them find XR to be useful in their work, however they see many other businesses where it fails.

Sometimes companies and organizations get to do something exciting with VR, but without anchoring it in the organization and without the product being used fully. Instead, start from the problem or the need and see what technology and approach could be suitable and successful. You don't need to focus too narrowly on the hardware, tools or technology (nor differentiate VR from AR), but instead look at areas of use, which is significant. Test it in a small agile prototype, first. In a relatively controlled environment, it is easier to make it work well when the user is doing something specific such as part of a learning session.

Technology and development
Some of the most significant recent XR developments mentioned by the interviewees are the tracking function of both VR and AR such as eye tracking with foveated rendering, an optimizing technique which uses an eye tracker integrated with a VR headset to reduce the rendering workload by reducing the image quality in the peripheral vision. You don't need to put a lot of effort into having the entire field-of-view perfectly rendered, instead it's adapting to the user. "*The technology (...) has matured enough that it works great and therefore it has*

become a natural part of everyday life. The tracking function, both in VR and AR, has been really successful" (Fay, interview, 2022.03.14).

The display technology is being developed to get a smaller display and thereby reduce headsets, which currently is very limiting - they need to be smoother and smaller to become more accepted as a consumer product. Many who use it feel that they are stepping outside their comfort zone. One of the interviewees mentioned "*It's not fully developed, and glasses can be smaller, but it works surprisingly well and I'm surprised myself.*" (Fay, interview, 2022.03.14) The interviewees all mention that in the future we will certainly have glasses or contact lenses, and that a lot of investment is going into that area of research.

Many of them think the Oculus quest has been an important technology that has been developed a lot. One of the interviewees adds "*VR is probably the trend that has helped the most in the business world*" (Percy, interview, 2022.03.27). Based on degree of establishment, VR is more established, linked to 3D graphics and 360 degrees. At the same time, there are many large platforms that use AR and 3D graphics in applications. Most of the interviewees think AR will be bigger than VR, especially AR glasses and lenses. The future challenge will be to incorporate other senses. Currently there are some companies that work a lot on haptic sensation. Kim and Fay argue that sound technology will increase in the future. Image has dominated, but sound and voice control will be increasingly important, as one of the main interfaces of new glasses is that they should be able to be integrated with voice controls. As for movement, you still have to move on a physical surface in reality or have a solution for how you transport yourself in the VR world, e.g. teleportation and omni directional treadmill, which is also being investigated.

> "*The fact that we can use the mobile phone for AR and 360 degrees is great - it enables wider use and adoption. The development of the camera is so technologically advanced and can now detect through scene recognition, which enables it to be technically and experientially better*" (Kim, interview, 2022.03.28).

Also, "*the threshold for getting started is lower and if one is interested in trying out and working on the technology themselves, one can do things without having to be a programmer*" (Fay, interview, 2022.03.14).

Integrating VR and AR brings many possibilities, using the advantages from both technologies. However the interviewees bring up that although the technology development is incredible, it still lacks applications and a device that fits everyone.

"*Technology changes all the time. You don't need to stare too narrowly at the hardware, tools or technology, nor differentiate VR from AR, but instead look at areas of use, what is significant.*" (Uanie, interview, 2022.03.14)

All of the interviewees touch upon that similarly to the Internet, XR is seen as something that will change or influence society. One of the interviews, Alex, describes how humans could have digital lives with virtual artifacts, moving from different platforms and interacting with our digital identities - blurring out physical boundaries. However, Kim adds that XR will still be one technology alongside others - in a so-called digital plenitude.

> "*Many will use several different types of technology, which we can see in media history. Just as people have different kinds of relationships with technology, this will also happen with XR, where some will use it more, and some less*" (Kim, interview, 2022.03.28).

Some of the potential opportunities and challenges mentioned by Kim are the possibilities of introducing AR and VR in open browser environments (www, html) so that it could be integrated with the technology and enable open source. A challenge is also to create less data heavy products that don't require much graphics. According to Uanie, there is the development of the actual hardware and software of the technology, but also 5G which will mean a lot for XR when it is expanded. Kim continues on the same discussion, adding that different trends come and go, where currently much is discussed around AI, giving rise to other types of ventures and investments.

Business and industry

One of the interviewees, Percy, describes that the technology is good but "forced", and that there is lost trust of the big players on the market. However, the world is waiting for them to release new products, and to guide them. "*It can be good if larger companies show some direction, to standardize certain things. However, it depends entirely on what business interests exist among these actors, which will also be reflected in how people use the*

technology" (Alex, interview, 2022.03.10). Although there is competition, new startups and the next generation of companies can still succeed and be outstanding, according to Percy. Companies that focus a little more on the early adopter phase will have it easier, as it justifies a certain type of investment.

> "*The hard part is convincing the rest of the world to start using XR. Some are very hesitant, may have never used XR or had a bad first-time experience. You have to work with it and maintain it and influence the companies organizationally so that more people take the technology seriously*" (Fay, interview, 2022.03.14).

"*Many still wonder what the metaverse is, the discussion is not dead but attempts are being made to find out more and what forms XR could be - the way trends work*" (Alex, 2022.03.10). At the same time the industry is "pushing" for metaverse and hypeing itself up, it is important to influence and lead, says Fay. Same goes for customers and citizens, to be active and take part in the discussion and development of the technology and market. All the interviewees bring up the fact that many people have still never tried the XR technology or are very against it. The more people who get to try a well-designed immersive experience with good applications the more opportunities for the XR industry.

Kim notes that one of the main challenges is in the user segment, how to find a market where you are not dependent on a certain hype or certain project funds, but that there is a sustainable economy for the XR companies. Kim continues by saying there is a danger in being very niche in technology. "*You need a greater breadth in media technology*" (Kim, interview, 2022.03.28), referring to companies that are too narrow in their product offering. "*When the hype is 'dead', you can have a problem*" (Kim, interview, 2022.03.28).

All the interviewees agree upon that one of the most important challenges is to find the business value and the right area of application so that it becomes a useful and successful product. Also the value should be anchored in the organization and integrated into the business. However, if XR is only suggested for the sake of the technology, it is being discouraged to be applied. In such cases, the full potential of the medium is not used.

"In comparison, there are some companies that dismiss XR or take it too casually, thinking they have no use for it, no use case - but miss out on a great chance of finding a user case or scaling their business" (Uanie, interview, 2022.03.14).

"AI is both a challenge and an opportunity. For example, it can help a lot with 3D environments and create cheaper production, as competence and working hours are expensive" (Kim, interview, 2022.03.28).

Social and ethical

There are ethical issues with people's online behavior, which Kim brings up:

"Especially women in VR have experienced verbal and cyberphysical sexual harassment, which symbolizes extraneous behavior and violence. Harassment and persecution is reflected in the digital landscape, and therefore legal boundaries need to be set, as well as human boundaries. There will be problems if you create a VR environment where people do not feel protected" (Kim, interview, 2022.03.28).

Another example is where data can be tracked or collected without consent, such as movement or body data that can detect defects or diseases of people, that the interviewees discuss. There are some guidelines set, but one of the interviews, Alex, warns that they are too low, and depends a lot on the hardware, the platform, the distribution. *"Surely any new platform that is unregulated will be exploited in one way or another"* (Uanie, interview, 2022.03.14). The interviewees think that the same ethical issues apply to XR as with other technologies. Within XR, the application can read more about the environment around you, such as the user's private homes. It is important not to leave the issue to individual companies. One needs to bring XR technology into a larger discussion to create standards, as the privacy issue needs to be resolved.

"Something I find important is that I do not work with VR because of VR itself, I work with education as I want people to learn. Otherwise, there is a risk that you push something in a direction that you did not foresee, that you do not see, which is negative." (Alex, 2022.03.10)

Per mentions that when people give away our data, we get better information, and in the best case you can sell or give biodata. However, it comes down to us not caring enough as humans about how our data is being used. "*A lot of personal data can be used and misused, which is a big problem we must be conscious and act upon it*" (Fay, interview, 2022.03.14)

> "*As it (XR) deals with digital products, a lot of metadata is created and aggregated. If there are larger companies behind this and for example, offer this for free or for a low sum, then there is the problem of ethical problems. What data about one's identity and privacy is collected and for what purposes is it used? Such problems with digital identities are larger societal problems, where some discussions are already underway, but it is an important dimension of the whole development. It is important not to think that you are doing something harmless*" (Alex, interview, 2022.03.10).

"*It is a societal phenomena, no one had the intention of creating this but yet this is the product of technology as how it is affecting and adapted by humans*" (Alex, interview, 2022.03.10). Alex continues to talk about how we are heading towards a generational shift in how we interact with the internet, where people will "give up" more and become more dependent on the digital artifacts, which will become more valuable.

> "*It will become even more important with cyber security and standards. Existing protections will not be enough as we should protect privacy from data breaches and data collection. More digital artifacts will also affect how money will flow and how different resources will be traded*" (Alex, interview, 2022.03.10).

Kim mentioned that we will have a world that becomes more digitally segregated:

> "*In general, the biggest problem with visions is that technology would take over. This type of technology, XR, will establish itself, in some spheres more than others, there will be breadth in use. Everything is moving, it is hard to say what the most advanced technology will be, but there will still be physical artifacts and very advanced VR environments. Technology changes but parts of our society shows that there will be variation. Media history shows that.*" (Kim, interview, 2022.03.28)

"People form a relationship with various artifacts and it can be enormously powerful visually. Depending on how you design interactions, it can affect people and their perception of reality. For example, there are risks such as various addictions. Some game developers think proactively and have strategies for how to design their digital experiences so that the player gets hooked and stays. Since we humans are in a certain way, biologically and have natural limitations, one should be aware that certain interactions with digital artifacts in a strong visual way have a strong impact." (Alex, 2022.03.10)

The interviewees find it challenging in finding XR's place and application for every industry:

"It is important to look at technology from a more specific point of view, using it as a good complement, and not just see it as a rescue. Then XR can be of enormous benefit as it creates opportunities that other technologies do not" (Kim, interview, 2022.03.28).

There are a huge number of approaches for XR to benefit society. For example, according to Percy, it can help to create boundless communities with citizen dialogues. Considering the different needs and accessibility of people, it can give access to education to a larger extent, in different variations and in a more sustainable and immersive way.

Uanie brings up many possibilities of engaging and involving more people in the process, such as in the creation of a new district.

"You can train personnel in work tasks that normally would be dangerous, and now you can do it in XR as many times as you want without anyone getting hurt. You can visualize things, engage and communicate with people who might not normally be reached or involved in certain situations or decisions" (Uanie, interview, 2022.03.14).

"Personally, I believe and hope that XR will be used to rebuild cities, visualize the right things for the right people in different forms so that cities can be rebuilt and become more sustainable. If you invest more in these areas, I hope it will be used to build that kind of future, a rescued future. (...) "There are different purposes for using XR - some use it more for the experience and play, while others want to use it to make

the world a better place, which is where I hope we're heading" (Alex, interview, 2022.03.10).

One example described by Uanie as an opportunity in the future for XR, is to be able to see the public environment through a pair of lenses or glasses and receive personal advertising.

Fay says it is almost easier to list what XR can not do, as XR can help with a lot of things - such as create more sustainable solutions and help us reach the global goals, like avoiding travel and building prototypes before production, simulating climate crises or poverty to actively work against it. "*Maybe it is possible to reach these goals if investing more actively in that type of nudging*" (Kim, interview, 2022.03.28). All the interviewees touch upon these topics and bring up additional possibilities of using XR for sustainable solutions.

6. Discussion

Based on the results, different topics will be discussed in relation to opportunities and challenges of XR. First the technological aspects will be brought up, such as the continuous development of XR, and its integration with other technologies. Secondly its impact on various industries and the market, as well as economical aspects. Thirdly, it's what is still lacking within the industry such as regulations and diversity. All will be summarized and visualized in prototype. After the conclusion future research will be proposed to the study.

Stakeholders within XR

Identifying key players and their roles within the XR startup landscape is vital for a comprehensive analysis. These stakeholders have been identified through the literature review analysis as well as during the interviews, where we as researchers have compiled a list of the stakeholders found during the research.

- Technology companies are the organizations that develop and provide XR hardware, software, and platforms. These companies contribute to the advancement of XR technologies and drive innovation in the field.

- Content developers play a crucial role in XR by creating immersive experiences, applications, and games. They include independent developers, studios, and companies that specialize in XR content production. These developers may focus on specific industries such as entertainment, education, healthcare, architecture, and training simulations.

- (End) users are the individuals or organizations that consume XR content and utilize XR technologies. This group includes consumers who purchase VR headsets for gaming or entertainment purposes, businesses that adopt AR for employee training or product visualization, educational institutions that incorporate XR into their curriculum, and healthcare providers who utilize XR for patient care.

- Industry and Enterprise: Various industries and enterprises have a stake in XR. They may include sectors such as gaming, entertainment, healthcare, education, manufacturing, automotive, retail, real estate, tourism, and more. These stakeholders explore XR as a means to enhance their operations, improve productivity, provide immersive customer experiences, or innovate in their respective fields.

- Universities, research institutions, and academic bodies contribute to XR through research, development, and education. They explore the potential applications of XR, conduct studies on its impact, and train future professionals in XR-related disciplines.

- Government agencies and regulatory bodies play a role in shaping XR policies, standards, and regulations. They may provide guidelines for privacy, safety, accessibility, and ethical use of XR technologies. They ensure responsible adoption and protect the interests of consumers and the public.

- There are organizations that advocate for the responsible and ethical use of XR technologies. They may focus on issues such as diversity and inclusion in XR, accessibility for people with disabilities, digital rights, and data privacy. These groups aim to ensure that XR is used in a way that benefits society.

- Investors and financial institutions play a crucial role in supporting XR companies, startups, and projects. They provide funding, resources, and expertise to accelerate the development and adoption of XR technologies.

These stakeholders interact and collaborate to drive the innovation, and adoption of XR technologies, shaping the future of immersive technologies and their applications in various industries and domains:
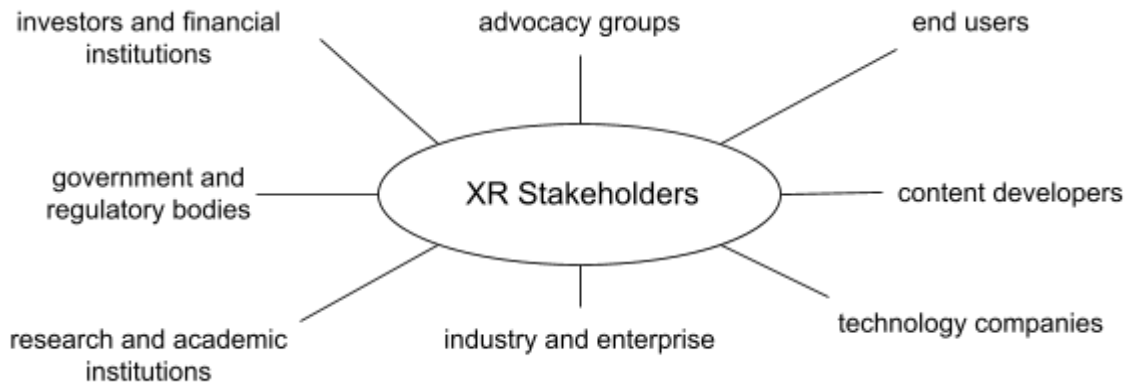
Figure 3: Stakeholders of XR (Johannesson & Karlsson, 2023)

Immature market

Considering the adoption curve theory, XR can be perceived as an immature market that is in the early stages of adoption (Rogers, 2003). An immature market is often in its early stages of innovation and is still exploring beneficial use-cases. An immature market can also be described as having limited competition, as can be seen in the XR landscape, as well as having an uncertainty over regulatory changes and ethical decisions. While innovators and early adopters have embraced XR and are exploring its possibilities, the technology is yet to gain widespread acceptance and practical applications that appeal to the early and late majority. This perception of XR as an immature market, which the study participants mention, does not imply that the technology lacks potential or value. Instead, it reflects the current stage of adoption and the need for further growth by finding more use-cases. To maximize the use of XR, it is crucial to emphasize the technology's potential to address real-world challenges. Overcoming the lack of comprehensive understanding and addressing the barriers of perceived risks and benefits will require increased awareness, clear demonstrations of benefits, and collaboration among stakeholders to explore and implement XR in innovative and impactful ways.

Although the investments in the XR market are growing, many of the challenges brought up during the study have a strong connection to both the slow adoption of XR technology and the XR market in its early stages. Some of the participants stated it is already a mature and applicable technology but that the market is still immature and emerging. However, it is important to note that market maturity can depend on the specific segment on XR technology and geographical region. Widespread consumer adoption has yet not occurred, especially

with VR devices, were not yet household items for the majority of consumers. There is still evolving hardware with significant improvements and iterations and therefore not yet fully matured in terms of design, comfort and functionality. There is a need for more diverse and high quality content to drive broader adoption.

The businesses behind XR still struggle with applying the technology on cases, utilizing its full potential. This can be attributed to several factors, including a lack of comprehensive understanding of XR's transformative potential (Berglund 2022) and the barriers of adoption posed by perceived risks and benefits (Chuach, 2019). When it comes to lack of comprehensive understanding, many companies and individuals may not fully grasp the potential of XR, and rather view XR as a novelty or entertainment technology. This limited understanding can hinder the exploration and implementation of XR in innovative ways. Without a clear understanding of the benefits the technology can provide the user, they may be hesitant to adopt XR. Without clear demonstrations of the technology's benefits, it becomes challenging to garner interest and adoption.

Continuous technological development

The technical challenges of XR reveal the complexity of the technological landscape. Advancements in XR require substantial resources, reflecting the need for continued investment in research and development. The challenges facing XR contribute to the perception of the XR market as immature and hinder the widespread adoption of XR technology. Key obstacles include the need for specialized hardware and software, as this is still undergoing significant improvements and iterations. This indicates that the technology is not yet fully matured in terms of design, comfort and functionality.

The need for interoperability standards reveals the challenges of a fragmented technological landscape. It highlights the importance of standardization to ensure that different technologies can work together. Compatibility across different devices and systems is crucial for successful XR adoption as well as integration with emerging technologies, according to the interviewees. Ensuring seamless performance and a consistent user experience across platforms is challenging due to the wide range of hardware models and operating systems (Matthews et al., 2021). Enhancing compatibility can enable users to engage with XR experiences seamlessly regardless of their preferred devices.

Negative first experiences can create hesitancy among potential users and hinder adoption. The results show that addressing this challenge could involve prioritizing positive user experiences by focusing on factors such as lightweight design, immersion, and adaptability. By increased research and development within these areas and successful improvements, this can decrease negative perceptions and encourage wider adoption. Addressing these concerns requires demonstrating the value and benefits of XR, and here is where the different stakeholders can play an important role of telling and showcasing the technology for the greater public. There is a need for guidance to remove adoption barriers for end users (Berglund, 2022) to support existing and new users. Examples of this could be user onboarding and training, trial periods and free access or mentorship as one of the companies used. Further stated, there needs to be strategies that promote tolerance for failure, as well as exploration for XR to fully use its potential to disrupt mainstream practices.

Limited and undemocratic content availability poses another barrier to XR adoption. To foster adoption, there is a need for a diverse and engaging range of high-quality content (Matthews et al., 2021). Ways of overcoming this challenge is by collaborative efforts from content creators and developers to expand content offerings and ensure inclusivity. Developing tools that allow remote collaboration between content creators in the first place, can overcome geographical barriers and enable artists and developers to collaborate seamlessly. Other examples could be user generated content platforms and partnerships with brands or communities as some of the companies bring up. It could also be cross-disciplinary collaboration, open-source initiatives, crowdsourcing initiatives, educational institutions involvement and collaborative workshops and events such as content hackathons. Thereby the XR businesses could provide compelling experiences that attract and retain users. These examples of collaboration could also lead to successful adoption of XR (Novakova and Starchon (2021).

Finding and retaining skilled developers proficient in XR can be difficult, as confirmed by the XR startups, particularly with limited resources. Large scale companies such as Microsoft, Meta and Apple can pick talented developers and offer higher salaries. Although some of the startups mentioned examples of employment that could be an option for them such as internships or part timers, these are usually short term solutions due to high turnover of staff. A market characterized by oligopoly is quite undemocratic, as more competition on the market could increase research and development within XR, which can lead to finding

more areas of use. Startups are therefore important in challenging the market and also the leading players. However there are alternative motivations why to work at startups as they can disrupt and challenge the industry in other ways than the bigger players. Bigger incumbents may overshoot the needs for low-end market customers, which leaves an opening for disruptive entrants. These entrants can then improve their offerings and move towards the high end market, where it is most profitable. Ways of overcoming this obstacle can be fostering collaborations such as some of the examples above, knowledge-sharing, and partnerships within the XR community (Novakova and Starchon, 2021). By pooling resources and expertise, the industry can drive innovation and enhance the development of XR technology - ImmersiveUnity is one example of a network community that does that (2023).

By collectively addressing these challenges, the XR market can advance along the adoption curve. These efforts will not only enhance user experiences but also demonstrate the value of XR in solving real-world problems and adding significant value across various domains.

Integrate with new technologies

Something brought up in the literature, observation and interviews was the impact new emerging technologies can have together with XR technology such as AI, 5G and later 6G. These new emerging technologies were discussed as technologies that can improve connection, immersiveness and enable new uses and cases of XR.

Rapid advancements within XR technology are driving innovation, pushing the boundaries of what is possible in digital experiences. Integrating XR with emerging technologies such as AI presents numerous opportunities as mentioned previously, but also introduces challenges. Hadziselimovic (2023) highlights technological challenges related to data processing, algorithm development, and social challenges such as user privacy when combining XR with AI. Whilst the technological challenges are associated with difficulty of development and integration, privacy refers to AI's ability to process personal data and information. By solving such issues, XR can unlock new levels of interactivity, immersion, and functionality which could help drive the adoption and transformative potential further.

Maksymyuk et al. (2023) state that AI has the potential to revolutionize the XR industry by enhancing object recognition and also by tracking movements and objects. This will improve

accuracy and realism in virtual environments (Reiners et al., 2021). It's also pointed out that AI can be used to detect and track users movements, such as hand movements for example. This would allow for more fluid and natural interactions in virtual worlds which could improve social virtual environments such as in remote collaboration (Matthews et al., 2021) and in the future metaverse. Improving the immersiveness and realism could increase the user's feeling of ''presence'', as it is currently lacking. This has the opportunity to increase the adoption rates, as Fay (interview, 2022.03.14) explains that people who have a bad first time experience have a chance to dislike XR. This can also, according to Chuach (2019), impact other people's view of XR and make them reluctant to try to adopt since people are influenced by each other, especially family and friends.

According to Matthews et al., (2021) AI is not seen as the only new technology that can improve XR technology. Also brought up was the integration of 5G. It was firstly stated as a challenge integrating it, but quickly explained during observations and interviews that it can turn into a big opportunity instead. 5G brings with it features such as network slicing and edge computing which will have significant implications for the direction of XR (Alriksson et al., 2021). This will improve the experience by offering faster and more reliable connectivity, being able to connect more devices, enabling the streaming of higher quality XR content and stability in crowded areas, thus increasing the usage of XR technology. The result from the study seems to prove that investing in 5G and 6G is a big opportunity for the future development of XR. By reducing lag and creating smoother interactions, immersiveness and responsiveness will increase which will improve the user experience. 5G will also improve bandwidth-intensive experiences, which means that XR can involve more high-resolution graphics and bigger worlds. It will also increase the number of users that can be in a virtual world simultaneously, which has been a hindrance for XR and is one of the reasons multiplayer hasn't grown as expected (Matthews et al., 2021). These changes are seen as improving the users experience while using XR technology, and thus making the users inclined to not only continue using XR but also speak positively about it which can increase adoption.

The integration of 6G is seen to take these improvements even further and more. 6G is expected to provide even faster and more reliable connections compared to 5G, and thus enabling even more engaging, realistic, lag-free and immersive experiences for users. 6G will also help XR technologies processing power, as 6G will be able to offload some of the

processing power to the network, which leads to a reduced burden on the XR device (Allam & Jones, 2021). The 6G network is also expected to be able to provide precise location information which can directly benefit some XR applications and services, especially when it comes to AR (Allam & Jones, 2021). Some AR applications overlay digital information onto real-world objects, and 6G will be able to provide more accurate digital information which can also help with discovering more use-cases for XR applications.

What was also brought up was that the combination of XR and 6G can play a role in shaping future sustainable and smart cities (Allam & Jones 2021). Firstly, help city planners and visualizers to plan different designs while at the same time assessing the impact it has on the surrounding environment and vice versa. XR can get real-time information and collect lots of data about public transportation, for example visualizing future transportation and infrastructure. One interviewee also mentions that it can help to create boundless opportunities with citizen dialogue, which can lead to creating a more democratic urban experience overall. XR can help visualize things and through collaborative XR platforms engage with people who might not normally be involved in the design process, which can increase the adoption of XR technology in society. It can lead to a more democratic design while creating or rebuilding certain districts for example. By converging different technologies, XR can enable new ways of creating, experiencing and interacting with different environments and with each other. This combination of technologies is enabling optimization of available resources and helps creating more sustainable worlds, allowing city planners and policymakers to make informed decisions. XR businesses can offer services such as design consultations, visualizations of development plans and also virtual tours of environments. It could also provide visualizations and tours of historical sites, showing the development of the geographical places.

Integrating emerging technologies such as AI, 5G and later 6G with XR technology creates new possibilities with the potential of reshaping and disrupting by enhancing the experiences and uses where XR technology can be used. The integration of these new technologies expands the potential for XR businesses by also offering new services such as design, visualizations and virtual tours of historical sites with real-time information. XR businesses can offer new experiences, attracting new customers and also create new revenue streams.

Impact on industries

New and immersive XR technologies are disrupting many various industries (Bolter et al., 2021) (Chuach, 2019). With accelerating digitalization, a need for more remote collaboration and more sustainable alternatives, even more industries and areas of use can be identified where XR can be applied and make an impact (Matthews et al., 2021). This is also established during both the observations and interviews, where the XR businesses express that they see opportunities for XR technology in new and unexplored markets.

One of the industries the interviewees foresee benefits with the use of XR is in education and job training, where the industry has already started to experience XRs potential disruption. The dependency on remote collaboration tools increases and the experience of it is as lifelike as possible, increasing efficiency in learning processes. Marr (2021) and Bolter et al. (2021) also discuss XR technologies opportunities in education and job training, explaining even further that it is the immersiveness and continuously increasing realism that are the key drivers that can enhance these industries. XR could in the future replace physical meetings, reducing the need for travel and thus having a more positive impact on the environment. The emphasis on remote collaboration in XR aligns with a society that values flexible work arrangements and global connectivity. There is a shift toward remote work and the need for innovative solutions to facilitate collaboration across distances, which is very positive for the development of XR - both in terms of investment and adoption opportunities.

The versatility of XR highlights its adaptability to a wide range of industries. Within healthcare the potential of XR can be of importance in improving healthcare delivery, accessibility and patient experiences. In education and training it can adapt educational practices to meet the evolving needs of learners. In entertainment and gaming XR can influence the gaming industry's ability to push technology forward. These examples mentioned indicate a societal commitment to leveraging technology for better healthcare, more effective and engaging learning methods, and entertaining experiences. XR can therefore contribute to positive societal change in many various ways.

This reflects a society that increasingly relies on technology to address various needs, from healthcare and education to entertainment and business. The extent to which society becomes dependent on technology has both positive and negative implications. The impact depends on

how technology is harnessed, regulated, and integrated into various aspects of life. Striking a balance between the benefits and drawbacks of technology is crucial, emphasizing responsible innovation, digital literacy, and ethical considerations to ensure that technology serves the best interests of society as a whole. The projected growth of the XR market suggests society's increasing reliance on XR technology for various aspects of life reflects the role of technology as a driver of economic growth.

According to the theory of disruptive innovation, industries adopt new technologies to gain advantage and to continue to meet ever evolving customer demands in a continuously developing digital society where new expectations are demanded (Christensen, 2013). These services or products most often start in more niche or low end markets, as with XR technologies, before trajectory upwards towards the high end of the market where it is most profitable. Two of the already mentioned examples are within the education and job training industry where XR is described as a potential disruptor to the traditional methods of learning and teaching. It was also mentioned during the interviews that using XR technology in job training is efficient both in time and performance, proving the potential disruption XR can have if it overcomes its barriers. Another example is the healthcare sector. Within healthcare XR can offer new opportunities when it comes to medical training for staff and virtual surgeries (Marr, 2021). It can also be used to help patients in their stroke rehabilitation progress (Bezegová, 2017). The key take away is that XR can provide interactive learning experiences that go beyond the traditional learning and training. This creates opportunities where XR can offer new and increased value to the industry, following along in the development and thus meeting ever evolving customer demands. Disruptive innovations, such as XR, often arise when new technologies or products challenge the existing ways in the industries while targeting niche markets (Christensen et. al., 2013), which is what XR technology is doing by penetrating into new markets resulting in new opportunities. XR is challenging norms in established industries by offering various new experiences and ways to interact with content. XR technology has the possibility to enhance the user experience whether that is within gaming, entertainment or education or job training industries. This immersiveness has the potential to transform and revolutionize industries.

At some point the disruptive technologies and businesses can decrease in technology newness and remain as sustaining within the newly penetrated markets. In that state, they would still be doing significant improvements on products that aim to sustain the position in an existing

market instead of disrupting, while continuing to meet customer demands in terms of price and performance.

High costs of XR

High costs associated with XR technology pose a significant challenge to its adoption, particularly in the early stages of market maturity (Bolter et al., 2021) (Marr, 2021). Innovators and early adopters are seen as tech enthusiasts and are more inclined to take risks and are often the first to invest in new and costly technologies like XR. These consumers are prepared to pay higher prices than the rest. Their willingness to invest depends on the potential benefits they see in XR, weighed against the financial implications. The early majority, representing a large portion of the market, tends to be more cautious and less willing to take risks and often wait to buy or try until they see the product or service's usefulness to not waste their money or time. High costs can act as a deterrent for this consumer segment, as they need to see a clear return on investment or benefits that outweigh the expenses associated with XR technology. Without a compelling case and cost justification, the early majority may hesitate to adopt XR.

XR faces investment challenges, especially considering the economic landscape characterized by inflation and post pandemic. Investments might be harder to secure and businesses may be more cautious about allocating funds to new and emerging technologies like XR. The skepticism surrounding XR and a potential decrease of hype that some of the study participants discuss can further impact the reluctance to invest. Also, perceived risks, including uncertainty about cost and product performance can create hesitancy among potential new users (Chuach, 2019). Companies and developers need to address these concerns through robust communication, providing evidence-based information about XR's benefits and security. By demonstrating how XR can, for example, improve learning experiences by enabling remote collaboration, simulate real-world scenarios and provide immersive data visualization, the technology's transformative potential becomes evident. Increased awareness about the benefits and successful use cases of XR can help overcome the perceived risks and encourage wider adoption.This can build trust and alleviate doubts surrounding the investment.

The current XR market could be seen as oligopoly, as there are a few large, leading firms with barriers preventing entry. Although the prices are currently high for the technology as it

is new, it is highly influenced by the dominating companies. There are different factors that can allow them to maintain higher prices and profit margins, such as economies of scale, high R&D costs as well as strong brand recognition. The development of lower-cost versions of XR technology, as reported by Bloomberg (2023b), indicates progress in addressing the accessibility barrier. As costs decrease, XR becomes more accessible to a wider range of users. However, it is not likely for businesses to reduce their prices for the sake of it, due to wanting to make as much profit as possible. The lowering of cost should come naturally as XR continues to develop as technology and more businesses are entering the market, creating more competition on the market. Businesses contemplating XR adoption evaluate the expected benefit-cost ratio. It is important to clearly demonstrate what benefits XR can bring, such as increased productivity, enhanced training, improved customer experiences, or cost savings in the long run. Establishing a strong business case that highlights the potential returns can help overcome concerns about cost.

Moreover, advancements in XR technology, including the development of glasses, lenses and the accessibility of AR offer alternatives that are comparatively more accessible and cost-effective than VR. AR, in particular, presents opportunities for businesses to harness XR's potential without incurring high implementation costs. The interviews and observations also bring up that AR has higher chances of being adopted earlier and easier than VR by the users, which might change the development of the technology and industry. This is mostly due to how accessible AR is for consumers by being integrated into smartphones, compared to the use of VR headsets. And although smartphones can have a relatively high price for the end consumer, it is practical for many different areas of use which is why it is so common to have one.

By addressing the cost challenges, demonstrating expected benefits, and mitigating perceived risks, XR can move along the adoption curve and attract a wider range of users. Lowering costs, coupled with strategic implementation in areas where XR provides unique advantages over traditional methods, can drive adoption and position XR as a valuable tool for businesses, while also offering potential cost-saving and sustainable solutions.

Lack of regulations and guidance

As a disruptive and emerging industry, XR operates in a regulatory landscape that is still evolving and adapting. Regulations tend to be reactive, responding to emerging issues rather than proactively guiding the development and use of XR technology. During the interviews with the XR professionals it was discussed that the XR landscape is lacking in regulations. They mentioned that there is a lack of standardization within XR about what is ethically correct, which Novakova & Starchon (2021) agrees with in their paper where they also express a need for more regulatory frameworks, explaining that it could help to hinder privacy violations, development of unethical content and provide safety for users. XR devices often collect personal data while also having the ability to record or collect views about the user's surroundings. Waiting too long to establish regulations or not taking appropriate action in setting boundaries can result in risks and negative consequences for users such as exposure of personal data and potential misuse by the companies. Some startups said during the observations that they tend to look at the leading entities for guidance. Although they insisted that they instead would want to see government agencies and regulatory bodies to provide the rules to make it more fair and safe for everyone.

This issue can be associated with the Hype Cycle's phases Technology Trigger and the Peak of Inflated Expectations (Fenn & Raskino, 1995). During the early stages of a technology's development there may be limited regulatory frameworks in place, resulting in a lack of clear guidelines of what is legal and ethically correct. As the technology gains traction and expectations rise, there is a need for regulatory intervention to address potential risks and ensure responsible development. Stakeholder involvement and engagement are crucial in the development of XR regulations. Government agencies, regulatory bodies and advocacy groups need to be actively involved in shaping regulations so that the users and creators of the technology feel safe.

Balancing technological advancements with privacy protection and ensuring equitable access and usage becomes important in a digital age (Hadziselimovic, 2023). The challenges reflect a society fighting with the pace of technological change. There's a need for regulatory bodies to adapt to emerging technologies and protect the public interest. Users need to feel safe by knowing what data is being collected and how it is being managed. It requires careful deliberation to strike a balance that safeguards individual rights and prevents the misuse of XR technology. It is important to recognize that technology, including XR, is a reflection of

society and humanity. Integrating XR with other emerging technologies such as AI offers numerous opportunities, as mentioned earlier. However, it does not guarantee ethical or responsible usage due to AI feeding on collecting data from users.

The lack of clear regulations in the XR industry, stemming from its disruptive nature, poses challenges for startups and the overall advancement of the technology. Waiting too long or not taking appropriate action in setting boundaries can lead to risks and negative consequences. Involving stakeholders, addressing privacy concerns, and balancing the impacts on democracy and individual rights are critical aspects of XR regulation. It is important to approach XR technology with a proactive mindset, considering its potential impacts and integrating it responsibly with other emerging technologies.

Lack of diversity and inclusion

There is a lack of diversity and inclusion in the XR industry and technology. This issue manifests in both the industry's structure which is often homogenous, eurocentric and dominated by white males which affect the technology's potential for bias and exclusion if not appropriately addressed. Failure to respect and act upon diversity and inclusion can lead to increased digital segregation and discrimination against certain individuals or groups and might even increase prejudices. There are critical cases where technology has been designed on biased data, which one of the XR founders mentioned. One example is in traffic where crash-test dummies typically are designed to look like the average man, which causes women to be 73 percent more likely to be injured in a car accident (CNN, 2022). During the observations it was mentioned that it is very important using synthetic data and to try working towards that constantly. When integrating XR with AI, the same applies. AI plays an important role in web data collection as it can process large amounts of data effectively by using automated tools such as bots or scripts to extract data from websites and users. Depending on what data is being accessible during this process, AI will generate data that might be used in current technology. This can create cultural and socioeconomic bias, and there's no guarantee this won't happen in XR unless regulations are set and there is ongoing work towards diversity and inclusion.

Diversity and inclusion efforts should therefore be integrated into the core values and practices of the organization, at all levels. Examples of ways of working towards that is by incorporating it into the business management in terms of diverse hiring practices, creating

and maintaining an inclusive company culture with continuous education and training. When it comes to the technology and the design companies can work towards inclusive design, content representation, accessibility and usability. By adhering to existing standards and guidelines as well as regularly testing XR applications, with a diverse user group or synthetic data, accessibility issues could be identified. Other examples to work towards diversity and inclusion could be through partnerships and collaborations such as with advocacy groups and users.

It is important to remember that as the technology and the industry is in constant development, continuous improvements are needed and standards need to be challenged. Companies need to regularly review and update strategies to adapt to changing circumstances and challenges as well as seek feedback from employees, users and stakeholders to make ongoing improvements. XR technology can be developed to serve a wider range of users and minimize the risk of perpetuating systemic biases. Absence of diversity in the XR industry and technology, as mentioned by the XR companies, can be seen as a challenge in multiple phases of the Hype Cycle (Fenn & Raskino, 1995). In the Peak of Inflated Expectations phase, there may be a dominant narrative or homogeneity within the industry, in XRs case middle class or above, limiting diverse perspectives and inclusive practices. Recognizing the importance of diversity and striving for inclusive design (Holmes, 2018)(Matthews et. al., 2021) aligns with the Slope of Enlightenment phase, where a deeper understanding of the technology's potential impact is sought. Stakeholders such as tech companies, developers and users in the XR ecosystem bear a responsibility in promoting diversity and inclusion, and must actively work towards inclusive practices and representation. This responsibility extends to various aspects, including the design process, investment decisions, and overall industry practices.

Viewing diversity and inclusion as an opportunity rather than just a challenge can bring out transformative changes in the XR industry and technology. By embracing diversity, more people can access and use XR technology. The industry can benefit from a broader range of ideas and perspectives, leading to innovative applications and solutions. Many times collaboration is brought up in the study, as something wanted not only by the startups and interviewees when working with XR but also something that is needed by people and society. This reflects a society that seeks engaging and inclusive digital experiences, which underscores the importance of creators in shaping the XR landscape. It can help unlock the

full potential of XR when it comes to using the technology in a way to address and solve global issues, such as environmental issues. It can also be used in ways to unite people, and increase democracy, creating positive societal impact. XR's capacity to revolutionize user engagement underscores society's growing demand for immersive and interactive experiences. This suggests that people are seeking more meaningful and interactive ways to connect with technology.

Matthews et al. (2021) raise important questions about designing XR technologies that are inclusive and minimize harm. They highlight the potential of XR to assist people with disabilities, mental conditions, and other marginalized groups. Inclusive design, rooted in a human-centered approach rather than solely focusing on technology can aid in the adoption of XR for more users than a certain segment or group. The challenge of making it accessible reflects the societal goal of inclusivity, ensuring that technology benefits everyone, regardless of their abilities or backgrounds. Not actively working towards the goal, implies risks for both the industry and society, as discrimination and digital segregation will increase.

Emphasizing diversity and inclusion as opportunities can lead to not only more accessible but also creative use of XR technology. Stakeholders have a responsibility to promote inclusive practices - by addressing these challenges and conducting further research, XR can be developed to be more accessible and beneficial for society and technology.

6.5 Prototype

Screenshots available in Appendix B.

As part of this study, a prototype is designed with the aim of enhancing the value and understanding of the XR topic. To visualize the data of the study and especially the analysis, we want to create a mindmap and make use of the advantages of 3D and immersiveness, to possibly increase understanding and engagement (Lion-Bailey et. al., 2023). The prototype is a 3D Force graph visualization based on a system created by Vasco Asturiano. The system is available as open source code on Github, from where the template was downloaded. The template is edited via a code editor, in this case Visual Studio code. In the code editor we then edited the Json file to fit our research area and keypoints.

The main node linking everything together is XR itself, representing its central part in the study. This node then links further into other nodes which are the topics of the discussion. These nodes then also link further into more nodes which represent keywords that connect to its specific node (see Figure 3). The prototype can help with contributing to the thesis with another kind of understanding, to get immersed in the subject ourselves as researchers as well as the audience of the thesis. The question is what happens with us and the audience when interpreting such a visualization.
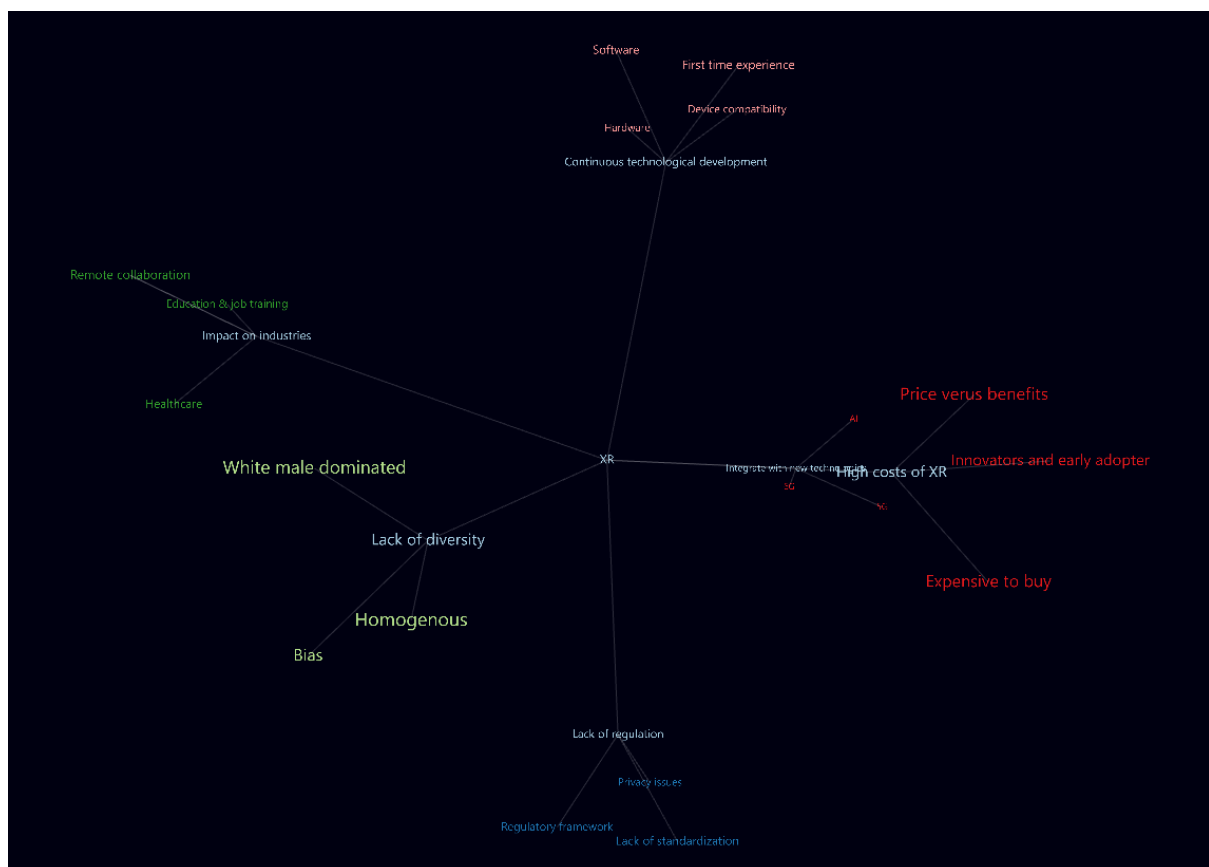

Figure 4: 3D visualization of analysis

The prototype is expected to visualize the key parts of the study, in a more interactive and immersive way. When working with the prototype, more ideas came to mind or what could possibly be added. As an attempt to consolidate the ideas, a comprehensive XR platform for XR businesses could be created for XR professionals and other stakeholders in the industry. The prototype could be a unified platform that offers training resources, social networking, market research tools, project management tools, and marketing tools - all in one place. The platform could utilize VR and AR technology to provide an immersive experience that helps

early-stage businesses better understand the XR industry and navigate the challenges they face. It could be designed to be accessible and free to use, with the goal of supporting entrepreneurs in the XR industry and fostering growth and innovation. Related to what is previously discussed about synergies in the thesis, both from a technology and business perspective, there are many positive effects of creating a platform for collaboration and fostering a culture of sharing knowledge, skills and resources. This is something we would like to contribute to with our research.

6.6 Conclusion

This study analyzes the opportunities and challenges experienced by XR startups within the rapidly evolving landscape of extended reality (XR) and the technology. By focusing on the current state of XR, this research provides a valuable insight into the direction in which the technology is heading. Despite the industry's constant development, examining its present state allows us to grasp the characteristics and emerging dynamics in the XR field. The opportunities can be seen as motivations for further adoption, application and exploration of future use-cases for XR. The challenges can be seen as factors that hinder or change that development.

The analysis of opportunities within the XR industry is bringing up the importance of both the consumers and businesses demands, along with the recent advancements in related technologies. Improved hardware, immersiveness and effectiveness increases the growth of the industry, which can increase the adoption of XR by consumers. Simultaneously, businesses in various industries such as education, job training and retail have recognized the potential of XR technology to enhance productivity, training and user engagement. Also, advancement in related technologies have contributed to the growth of XR businesses. The integration and synergies with these emerging technologies such as AI and 6G paves the way for new and improved experiences for customers, as well as enabling new uses for the technology. By understanding these drivers of growth, early stage XR businesses can position themselves to enter the expanding market and gain a competitive edge.

In conclusion, this study offers a snapshot of the XR industry at a specific moment, acknowledging its constant evolution. By tailoring research inquiries, accommodating ongoing developments, and adopting a holistic and critical perspective, this analysis aims to

contribute to a deeper understanding of the opportunities and challenges experienced within the dynamic landscape of extended reality technologies. It provides a comprehensive and reliable understanding of the XR industry, which gives valuable insights for entrepreneurs and stakeholders.

The opportunities and challenges of XR technology provide a nuanced view of the intersection between technology and society. They underscore the potential benefits of technological innovation but also emphasize the importance of addressing ethical, social, and accessibility concerns to ensure that technology serves the best interests of society as a whole.

6.7 Future research

Although this thesis has addressed several important aspects of XR there are still many directions for further research that still are yet explored. It would be meaningful to look further into a specific segment (see 1.1 Market growth and segments) and to compare different studies made. As the technology and industry is constantly evolving it would be very interesting to see the difference of a similar study only looking at what has happened in a short future.

This study is using early stage businesses, and looking at other businesses such as XR scale-ups could show what challenges and opportunities they are facing and if these would be much different or the same as the XR startups. It would also be of interest to further distinguish the findings of businesses within the XR market from general challenges for startups. To enhance the validity and credibility of the findings and mitigate the presence of research bias in the study, triangulation could be an option in future studies, using quantitative methods. For example, adding a questionnaire or survey with quantitative and qualitative questions, to address the research question.

However, there are some potential areas for future research that could be delved deeper into. One area for future research is the development of sustainable business models for early stage XR businesses. This could involve exploring alternative revenue streams, such as licensing or

subscription models, and assessing the feasibility of different pricing strategies within the context of the XR industry. As XR technologies continue to evolve, there is a need for research that focuses on user experience and how it can be improved. This could involve conducting usability studies to identify pain points and areas for improvement. It could also involve investigating the potential benefits of incorporating emerging technologies such as haptic feedback or eye-tracking within XR products.

Given the capital-intensive nature of XR businesses, future research could explore the investment landscape for early stage XR startups. This could involve assessing the availability of funding sources and exploring the factors that influence investor decision-making specifically within the context of the XR industry. There are many exciting opportunities for future research in the field of XR and early stage business. As the technology continues to evolve and mature, it is likely that new challenges and opportunities will emerge in the future, providing even more opportunity for continued exploration and discovery. However, we do not aim to provide any specific recommendations for businesses, as a challenge for one business can be an opportunity for another. Many businesses mentioned that often something can be both a challenge and opportunity even for one single business, depending on how they are facing it and what resources they have. This is something that can be characterized by the stages the XR businesses are in. It would therefore be interesting to look at how these early stage businesses differ in their experienced opportunities and challenges in comparison with scale-ups and more mature businesses.

Considering the societal context within which XR startups operate is crucial. The interplay between technology and society shapes the landscape in which these startups navigate, which is constantly evolving. Understanding how XR technologies intersect with cultural, ethical, and regulatory aspects provides a deeper understanding of the challenges and opportunities faced by startups in the XR domain. A nuanced and reflective approach is therefore fundamental to this analysis. By exemplifying specific scenarios and placing them within a broader context, the study aims to paint a comprehensive picture of the XR startup landscape. This approach encourages critical thinking and enables a deeper exploration of the opportunities and challenges inherent in the industry.

To gain a holistic understanding, diverse research angles are essential—embracing technical, socio-cultural, and economic dimensions. The pace of research must keep up the technology's

constant development to stay relevant and critical. A thorough exploration of XR's pros and cons as well as opportunities and challenges, including demographics and societal impact, completes the picture. Through collaborative and ongoing research, the XR's changing landscape can be navigated.

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8. Appendix

Appendix A : Interview guides

Observations of XR businesses

To categorize the businesses, we looked into:

- Company name
- Category
- Industry
- USP
- Problem/Solution
- Opportunities
- Challenges

Two questions are asked to the businesses:
- What opportunities are you currently facing in the XR industry?
- What challenges are you currently facing in the XR industry?

Interviews with XR professionals

We are two master students studying current opportunities and challenges within the XR industry. We will conduct the interview in a way of semi-structured questions, meaning relatively open-ended and divided into four different themes: Technology and development, user experience and design, business and industry and lastly, social and ethical implications. Before starting asking the questions, we would like to ask for consent and then begin with you telling us a little bit about your role and background within the field of XR.

- Describe your role and background within the field of XR.
- Can you talk a bit about the current landscape/industry of XR?

1. Technology and Development: This theme could explore the current state of XR technology and development, including emerging technologies, challenges in the development process, and opportunities for innovation. Potential questions could include:

   - Describe some of the most significant recent developments in XR technology and what potential they have for the industry?
   - What technical challenges are faced within the XR industry? How are these challenges overcome?
   - What emerging technologies do you see as having the most potential for disrupting the XR industry, and why?

2. Business and Industry: This theme could explore the business and industry aspects of XR, including market trends, business models, and challenges facing companies in the XR space. Potential questions could include:

   - What are some current trends in the XR market, and where do you see the industry heading in the future?
   - What are the key drivers of growth within XR?
   - What are some of the biggest challenges facing companies in the XR space, and what strategies do you think are the most effective for addressing them?

3. Social and Ethical: This theme could examine the social and ethical implications of XR, including issues related to privacy, ethics, and the impact of XR on society. Potential questions could include:

   - What ethical concerns do you see emerging in the XR space, and what do you believe can be done to address them?
   - How can XR be used to benefit society, and what potential drawbacks should we be aware of?
   - What impact do you think XR will have on privacy, and how can we ensure user data is protected?
   - What do you think the future of XR will look like, from a societal perspective?
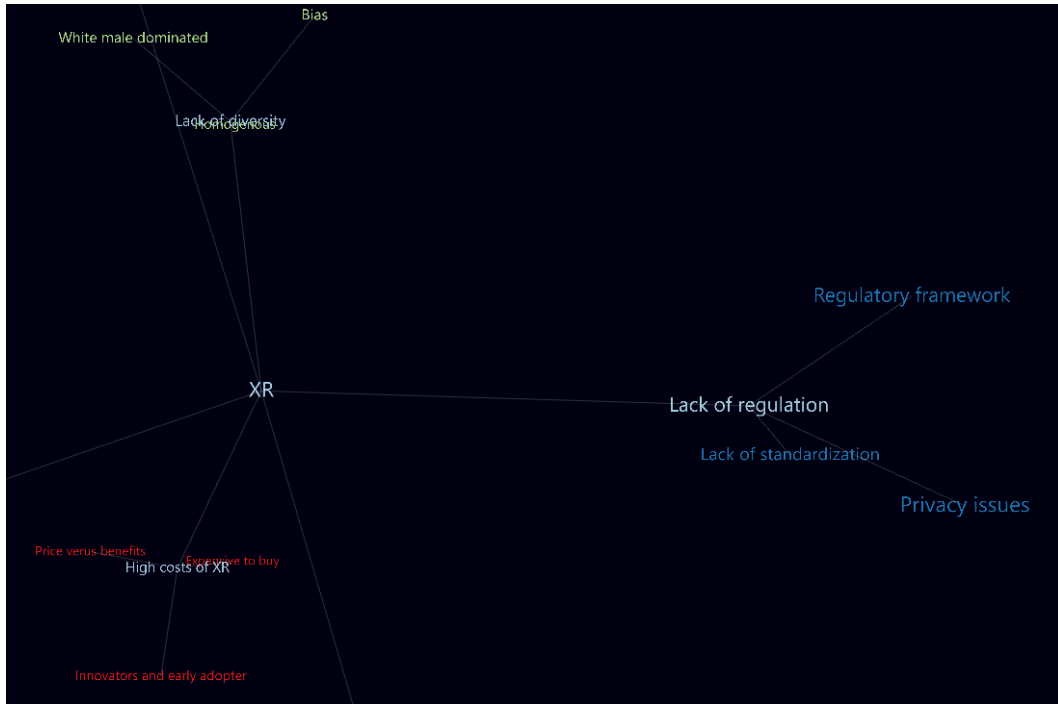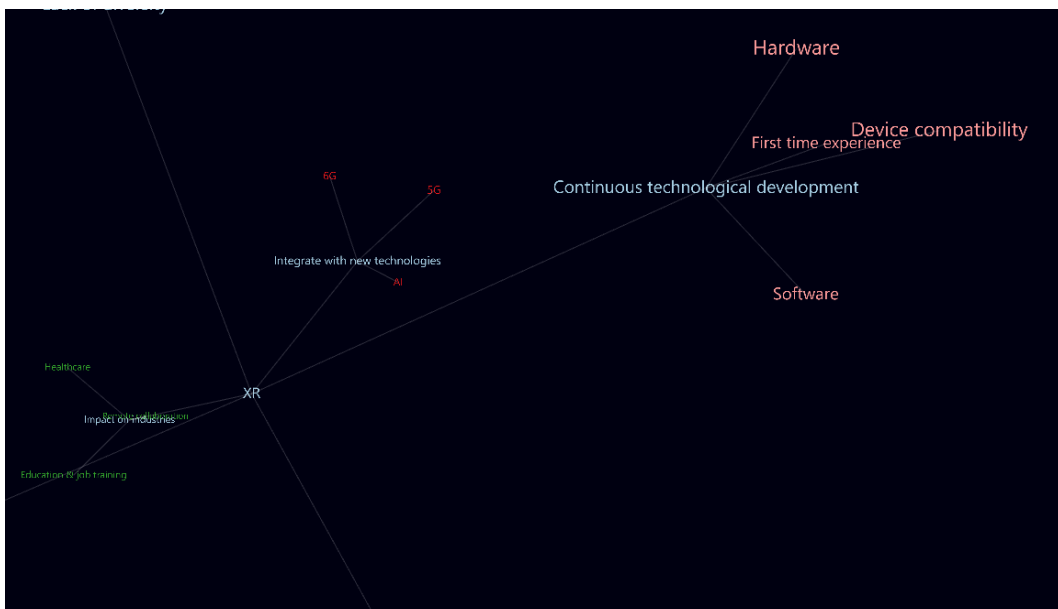
Appendix B : Prototype of mindmap

Figure 5: Prototype of 3D visualization

Figure 6: Prototype of 3D visualization