Medien Netzwerk NRW

EXTENDED/CROSS REALITY (XR) IN GERMANY 2022

Metaverse, Digital Ecosystems & Development of the XR Sector

Technology
Arts Sciences
TH Köln

Prof. Christian Zabel

Prof. Gernot Heisenberg

Daniel O'Brien (M.Sc.)

Cologne, 08/30/2022

XR

Medien Netzwerk NRW

A Study by TH Köln

Client:

Mediennetzwerk.NRW
c/o Mediencluster NRW GmbH
Kaistrasse 14 | 40221 Düsseldorf
info@medien.nrw | www.medien.nrw

Mediennetzwerk.NRW supports development of the digital media sector on behalf of the State Government of North Rhine-Westphalia, focusing on games, VR/AR, web video and mobile through cross-sector networking and mediation. It offers comprehensive information services to start-ups and young creatives. Collaborating with its partners, it raises the visibility of the media location NRW and its companies at trade shows and in markets on the national and international stage. Mediennetzwerk.NRW is financed by the State of North Rhine-Westphalia and with funds from the European Regional Development Fund (ERDF) and is a project by Mediencluster NRW GmbH, a wholly owned subsidiary of Film- und Medienstiftung NRW GmbH.

Editorial cooperation: Svetlana Myshkina and Jasmin Kessler, TH Köln
Layout: hoop-de-la design

Status of the research: July 4, 2022

Table of Contents

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

List of Tables

List of Figures

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

0. EXECUTIVE SUMMARY

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

0.1. Study Design

- The design of the study combines several investigation steps in a proven manner: Desk research, complete survey and online survey of companies producing virtual, mixed and augmented reality (together: XR companies) in Germany.
- The study presents the size, structure and development of the XR sector, the business climate and prospects within the VR, MR and AR segments over the next 18 months. It also investigates the relevance of digital ecosystems and the trend topic of the metaverse for German XR companies.
- A total of 1,613 XR companies were identified in Germany. The 1,456 companies reached by email were invited to take part in an online survey in June 2022. The data from 130 companies (participation rate: 8.9%) were weighted and included in the analyses, so that the data are representative in terms of regional distribution, company age and size. 89 percent of the respondents were owners, partners, directors or members of the management board. Some questions were not evaluated on a representative weighted basis due, for example, to the consideration of sub-samples. The number of participants may differ in these cases.

0.2. Size and Development of the XR Sector in Germany

- Overall, the German XR industry is highly attractive and experiencing dynamic growth. This is evidenced by numerous company startups and market entries, strong growth in revenue and XR employees and by the favorable business prospects.
- In 2022, the German XR industry numbers 1613 companies in total, 260 (+19%) more than in the previous year and almost four times as many as compared to the first survey in 2017 (approx. 420 companies – estimated for Germany based on data for NRW).
- On average, 98 companies were founded each year in the area of XR between 2015 and 2021. Over a third of the companies (37.9%) did not enter the market until 2016. By contrast, barely any business closures have been registered. On average, the number of XR companies established per year outstrips the figures for those exiting the market by a factor of four – despite the COVID-19 pandemic.

- Small and medium-sized enterprises dominate the sector: 56.6 percent of the companies have ten or fewer employees, while 29.7 percent have between 11 and 50. Only 2.8 percent of the companies employ more than 1,000 people (this also includes corporations that do not primarily focus on XR).
- If only employees dedicated to XR are considered, 39 percent of the companies already have more than six employees in this area; 20 percent even have more than 10.
- The XR companies are able to generate increasing revenues with their products and services. Just over half the companies (51%) already achieved annual revenues of over €100,000 with XR in 2021. 16 percent of the companies even generated revenue in excess of €1 million with XR – more than double the share in a year-on-year comparison. This may be the result of efforts to offer proprietary products and platforms instead of contract manufacturing.
- The improved revenue structure and numerous market entries have led to a significant increase in revenue in the sector compared to the previous year. As a result, the industry generated an estimated €490–550 million in 2021, up from €380–420 million in the 2020 pandemic year. This is equivalent to growth of 29, i.e. 31 percent. The XR sector therefore occupies a mid-table position of dynamically growing sectors such as German games producers/publishers or influencer marketing.
- Growth is having a positive impact on employment in the sector as well. In 2021, XR companies (excluding corporations with more than 1,000 employees, in which XR is likely to be only a secondary field) employed an estimated 57,200 people in total. This is equivalent a rise of 11 percent year-on-year. If one merely considers the employees who focus on XR, an estimated 12,200 to 12,900 people are active in this field alone (on average: +24% compared to 2020).
- Revenues have therefore registered stronger growth than employment. This points to the considerable importance of scale and network effects in the production of XR services and hardware. At the same time, there has been a significant increase in the share of XR employees relative to total headcount, which indicates that companies are placing a stronger focus on XR.

0.3. Regional Structure of the XR Sector in Germany

- North Rhine-Westphalia is still the largest XR location with the highest estimated cumulative XR revenue (€104–117 million; mean value of the two estimation ranges: €111 million) and the largest number of XR employees (2,600–2,750 XR employees; mean value: 2,675). Following in second and third place are the federal states of Bavaria (mean values in each case: €90 million in revenue; 2,175 XR employees) and Berlin (€83 million; 2,025 XR employees). Baden-Württemberg (€65 million in revenue; 1,575 XR employees) and Hamburg (€40 million; 925 XR employees) ranked fourth and fifth, respectively.
- In total, the 1,613 XR companies maintained 2,043 primary and secondary locations in 2022. Most of the branch offices were in NRW (428/+12% compared to 2021), followed by Bavaria (358/+20%), Berlin (321/+18%) and Baden-Württemberg (253/+14%).
- Included in the largest regional clusters according to the number of primary and secondary locations are Berlin (321), Munich (181), Hamburg (160), Cologne (128), Düsseldorf (71), Stuttgart (61) and Frankfurt am Main (44). Of the four major locations, Munich and Cologne reported the largest increase in the number of companies compared to the previous year.

0.4. XR Company Offerings

- XR is the principal field of operation for 39 percent of the companies, accounting for at least 75 percent of corporate activities in these companies. Another 25 percent describe XR as a significant field of operation (approx. 50% of activities).
- Most XR companies operate as application developers (80% frequently/on a large scale). Consulting services are also common (38% frequently/42% rarely). Another significant proportion of the companies operate also as software resellers/integrators (22% frequently/24% rarely) and producers (27%/27%).
- The applications by most of the surveyed companies build on the 'AR (smartphone)' category (63%) – which was investigated for the first time – and full-feature VR (61%/-2% compared to 2021). Mixed reality offerings follow in third place, accounting for 44% (-4% compared to 2021).
- Just under a third (32%) are specialized in one device category, mostly full feature VR (49%) or smartphone-based AR (28%). However, 68 percent of the companies are active in at least two device classes.

- Product presentations are frequently offered by 55 percent of the companies, while 23 percent are less often active in this field. This is followed by design and simulation (79% at least rarely/+11% compared to the 2021 survey), XR training (73%/+2%) and production/ maintenance/service (55%/+1%). The figures for conferencing/collaboration (52%/-5%) and information/entertainment (50%/-7%) are declining. Games are frequently relevant for 22% and to a lesser extent for another 27 percent.

0.5. Customer Structure among the XR Companies

- The XR companies have a clear B2B focus. Only just under eight percent of the companies are predominantly focused on the B2C market (2021: 5%). But 37 percent state that they at least address B2C markets along with the B2B markets.
- The XR enterprises serve customers (companies) from five sectors on average. Only 14 percent are focused on one sector alone. XR firms most frequently work for the manufacturing sector (66%), especially for the automotive industry and mechanical engineering (both 41%). In second place comes the arts and entertainment segment (55%), followed by media, information and communication (52%). The manufacturing sector is also described as the most important customer segment by a clear margin (29%).

0.6. Business Climate Index

- Overall, the mood in the German XR has deteriorated somewhat: The Index reaches a total score of 68.4 (of 100 possible points), which is equivalent to a decline of 1.2 points compared to 2021.
- This trend may seem highly surprising as (presumably at least) the worst phase of the COVID-19 pandemic appears to be over in 2022 and the sector has experienced a positive development overall. But it is evident nonetheless that the current economic and geopolitical risks are having a negative impact on the business climate.
- Although demand (+0.4 points on a 10-point scale), order backlog (+0.5) and production activity (+0.5) have improved slightly looking back to the last survey, the indicators going forward are showing a negative trend.

- Development of the current order backlog (-0.7), the sentiment for the next 12 months (-0.8) and economic prospects (-0.7) in particular are viewed critically.
- Overall, the companies rate their current order backlog as too small, with a value of 3.5. The outlook for manufacturing activity in the year ahead receives the best rating (7.5).
- The business climate in the sector varies significantly from company to company. Small enterprises with up to five employees, for instance, rate the business climate in their sector at only 64.4 points; by contrast, companies with more than 10 employees returned a significantly more positive rating of 71.9 points. This applies also to companies that are specialized in XR, who rated the situation significantly better at 72.4 (vs. 61.7 percent of the companies with little specialization in XR).
- The Business Climate Index underlines once again the benefits of specialization and scaling that are already evident in the revenue figures: Large and focused companies are in a better position to profit from opportunities in the XR sector and therefore have a more positive assessment of their possibilities and prospects.

0.7. Prospects for the XR Markets in the Next 18 Months

- VR: Respondents continue to see the most attractive forms of offering in the areas of virtual training (65%/-5% compared to 2021), design/simulation applications (46%/+8%) and conferencing/collaboration solutions (40%/-11%). The low distribution of devices (53%/-3% compared to 2021) and the low utility value (50%/+16%) are seen as the greatest obstacles. By contrast, the low awareness of VR is less frequently perceived as an obstacle (47%/-14%).
- AR: Product presentations and experiences are expected to hold the greatest potential (74%/+12% compared to 2021), ahead of training applications (70%/+11%) and B2B use of AR in the area of production, maintenance and service (44%/-10%). However, respondents view information and entertainment offerings increasingly critically (26%/-23%). Lack of awareness and the need for explanation are the greatest obstacles to the growth of AR (61%/+7%), followed by a low prioritization compared to other topics. A lack of high-end devices is less frequently cited as a critical hurdle than in the previous year (35%/-14%).

- MR: 75 percent of respondents see considerable potential in training (-7% compared to 2021). The expectations for applications in production/maintenance/service have risen slightly (70%/+6%). The more positive assessment for conferencing/collaboration is even more pronounced (65%/+15%); this category is now on a par with design and simulation solutions. There have been stark changes compared to last year in the assessment of the most significant obstacles in the MR segment. Lack of awareness/distribution remains the most significant obstacle (60%/-4% compared to 2021). By contrast, low device distribution (35%/-22%) and low utility value (25%/-32%) are perceived less frequently as obstacles. The lack of standards (50%/-4%) and device quality (40%/+8%) now rank second and third among the obstacles.

0.8. Digital Ecosystems

- Digital ecosystems (Digital Business Ecosystems, DBE) are increasingly important in Germany. This is reflected in the XR segment as well, where 68 percent of German XR companies use the Unity DBE. 65 percent are active in the Oculus/Meta DBE and 44 percent in the Unreal Engine DBE.
- Just under 18 percent stated that they concentrate only on one DBE. The majority (53%) used up to 3 different DBEs. 47 percent of the respondent companies in the representative survey were involved in 4 DBEs or more, with four DBEs being the most common response (23%).
- Just over half (51%) of the XR enterprises state that they fully or predominately pursue a strategy of alignment with different DBEs. By contrast, just under a fifth stated that they are predominantly or exclusively focused on just one DBE.
- Oculus/Meta is viewed as the most important single DBE (32% of responses). It is followed by Apple (19%), which is very important for the AR market. HTC comes next, albeit by a considerable margin (14%), as a VR-based hardware ecosystem.
- Broadly speaking, contribution to the most important hardware DBE is considered to be very significant: On average, the companies rated this factor with a value of 4.9 on a 7-point scale, affirming its ability to increase performance. At 5.5, the value for companies that indicated Apple or Google as their most important hardware DBE is particularly high.

- Their own role in the DBE is interpreted far more conservatively in contrast. This means that participating in the most important DBE can help a company to achieve its own targets. But other companies can only benefit to a lesser extent from the fact that the respondent enterprise is active in the DBE.
- Companies evaluate collaboration with other enterprises in a DBE very differently: Although this plays a major strategic role for about 50 percent of the companies, the other half of respondents take a different view.

0.9. Evaluation of the Metaverse

- The concept of the metaverse is the subject of intense and controversial discussion not only in the XR sector, but also far beyond. German XR enterprises believe that the metaverse has the potential to become very important for their future business. 70 percent of the companies gave the metaverse a score of 5 or higher on a 7-point scale.
- The enterprises believe that the greatest potential for the metaverse is in the B2C market: Only just under one in five companies (19%) believe that the metaverse will reveal its greatest economic potential primarily in the business sector.
- XR companies are preparing for the metaverse: Most frequently, the companies are monitoring current market developments (61%) and keeping their employees informed (51%). They also use the term in their own marketing, for instance in customer workshops or (38%) corporate communications (31%). A respectable quarter of respondents have already developed their own strategy in regard to the metaverse or have conducted smaller tests, e.g. on individual platforms.
- 52 percent believe they are fully or largely prepared for the challenges of the metaverse.
- The surveyed companies consider virtual reality (80%) to be a relevant technology for the future, ahead of mixed (70%) and augmented reality (68%). This is followed by adequate transmission rates via 5G (58%), artificial intelligence (49%) and open standards, for instance via OpenXR (47%).
- At present, the technologies that XR companies believe to be important for the metaverse are used comparatively rarely overall. Mixed reality and 5G/modern transmission technologies are apparently lagging behind in particular.

- The respondents believe that limited knowledge among users (59%) and the ambiguous definition of terms (36%) present the most significant obstacles to implementation of the metaverse. In second place, however, is the concern that the metaverse might consist of a multitude of isolated individual worlds without interoperability (43%). Unclear business models (38%), inadequate hardware performance (37%) or insufficient transmission speeds (36%) are viewed as other significant obstacles.
- There is a lack of agreement concerning the future structure of the metaverse: While a good third (34%) assume that a few central providers will – like in other digital markets – dominate this field, a group of about the same size (35%) believe it possible that the metaverse will be decentralized, e.g. via Web3 technologies/structures.

1. PROBLEM & OBJECTIVE SETTING

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

1.1. Initial Position

This is the fifth time that TH Köln has conducted this study to examine the local XR industry on behalf of Mediencluster NRW GmbH, a subsidiary of Film- und Medienstiftung NRW. Aside from the two surveys on the North Rhine-Westphalian sector, there have now been three studies on the nationwide XR (extended or cross reality) sector in Germany. By this we mean all companies that create products and services in the field of virtual, mixed or augmented reality (but not firms that employ XR as users).

This continuous monitoring enables tracking of the dynamic development of this growth sector. For instance, the number of Germany-based companies offering XR in a wider sense has risen sharply from an estimated number of just over 400 in 2017 to 1,613 in 2022. Included in this are many companies that have added XR to their product portfolio, as well as a large number of newly established startups. 60 of the companies we were able to identify during our extensive online research have come into existence since 2021.

This momentum is also highly positive with regard to the generated value added and revenue in the German XR sector. We estimated the revenues of the German XR sector for the first time in our last study. According to our projection, the German XR industry generated an estimated total revenue of €380 to €420 million in 2020, which is roughly equivalent to the revenues of German games publishers. A positive trend was noted for 2021 as well, with revenue now ranging between €490 and €550 million – a rise of around 30 percent.

Repeating the study is an especially suitable method to track these developments, especially as it provides a complete survey of all German XR companies and because the findings are representative with regard to the core attributes of the companies – which may offer a considerable advantage compared to potentially biased convenience samples. We have retained many of the proven elements from previous years in this study, in order to enable comparison. This includes, of course, a description of the companies in terms of their regional distribution, size, revenue and areas of activity. We also surveyed the Business Climate Index in the XR sector again in 2022.

Furthermore, the study explores two current and highly relevant themes that were investigated for the first time. One of them is the recently initiated discussion on the 'metaverse'. Numerous companies, among them Disney, have come forward with their own plans since Meta CEO Mark Zuckerberg announced his intention to structure the entire company around this new virtual reality. Prior to that, platform games such as Fortnite or Roblox had achieved

considerable success with an innovative blend of real and virtual worlds; some observers already count these games as a potential part of the metaverse. Adding to this is the recent boom in AR software such as WebAR, which is continuing to strengthen this trend.

On the other hand, the metaverse debate emphasizes once again the role of the major international platform providers. Doing business with these enterprises is already a key competitive factor for companies in Germany. And although the relationships are asymmetrical, the platform operators have an interest in tying selected partners to their platforms as complementors. It is only logical, therefore, that collaborations and reciprocal relationships can be observed. However, these relationships and strategies of 'non-focal actors' have barely been explored in the literature on digital business ecosystems. Here, the study provides valuable information that is highly relevant from both a practical and scientific perspective.

The research in this study dates from June 4, 2022.

This report does not use the masculine and feminine forms simultaneously in order to improve legibility. The generic masculine is used and applies to all genders equally.

1.2. Research Design

This study describes the structure of the German XR sector based on a survey of the population, i.e. all companies active in this market. A representative survey of the German XR companies was also conducted on this basis as an accompanying measure. In terms of content, the study focuses on the following four issues:

Q1: How large is the sector of XR-producing companies in Germany in terms of revenue and number of employees?

Q2: How is the XR sector in Germany structured at regional level?

Q3: How do the companies assess the short- and medium-term development of the sector with regard to the business situation and the potential within the VR, MR and AR submarkets?

Q4: How do the enterprises in the German XR sector structure their relationships with the major platform companies in their sector?

Q5: How do the German XR companies assess current developments with regard to the metaverse?

In order to be able to answer the research questions, the key actors in the North Rhine-Westphalian XR sector were identified by means of our own research (desk research). We were able to build on the dataset acquired in previous years for this purpose. Companies that had already been registered were checked and updated once again in order to record any changes (e.g. business closures, relocation of the company headquarters). Supplementary online research (online, technical and economic databases) was then conducted using the same methods as in the previous years. For this purpose, research sheets were tabulated with synonyms, abbreviations, and generic/sub-terms for relevant vocabulary used in the XR sector. This enabled the identification of the following relevant search terms and their abbreviations:

- Virtual reality (synonym: virtual world)
- Augmented reality (synonym: extended reality)
- Augmented virtuality (synonym: extended virtuality)
- Mixed reality
- Cross reality (synonyms: X reality, extended reality)
- Metaverse
- Company (synonym: business, enterprise, firm etc.)
- Federal states and cities (e.g. North Rhine-Westphalia, Cologne, Bavaria, Berlin, etc.)

The second step in the research involved preparing a table of additional relevant terms. These terms include, on the one hand, words relating to the various sectors (e.g. architecture, construction, real estate, art, media, telemedia, medicine, health, industry, etc.) and, on the other hand, words associated with the application areas (e.g. development, research, design, simulation, manufacturing, maintenance, service, collaboration, consulting, support systems, etc.). In order to expand the conceptual complex of the term 'company', vocabulary such as business idea, business, business startup or startup, among others, were considered in the course of the research.

In the third search step, Boolean operators were used to create combined search terms, which are known as 'search strings'. They were entered in a variety of search engines and access points to identify actors in the German XR sector. Here are two examples of Boolean operations with OR and AND operators:

- (Virtual Reality | VR) AND (Business | Company | Laboratory | Agency) AND (NRW | Bavaria | Cologne | Berlin)
- (Virtual | Augmented | Mixed) AND Reality) OR ((AR | VR) AND (GmbH | UG | AG) [LLC| Ltd. | PLC] AND (Cologne | Berlin))

Like in previous years, the search engines used were Google, Bing, DuckDuckGo, Metager and Startpage. Companies were also researched on a variety of portals and social media platforms. Among others, these portals included dasauge.de, firmenabc.de, fiverr.com, firmenwissen.de, firmenregister.de and various job boards such as indeed.de, stepstone.de, monster.de and stellenwerk.de. The paid company databases Northdata and – for the first time – EchoBot were also accessed. Among the social media platforms investigated were Facebook, Instagram, LinkedIn and XING. Groups with topics relating to the XR sector were identified on these social networks and their group members researched for XR companies.

The final investigative step again involved researching companies on platforms or at conferences, universities and trade shows with a reference to the XR sector in Germany. Universities and institutes were also researched for XR-related curricula to subsequently identify collaborations with companies within the sector.

The result of this research is n=1,613 companies active in the XR sector in Germany (a total of 1,683 companies were identified, but 23 ceased operations in 2022; 47 companies whose activity status was unclear were also not included). Based on company information (e.g. on their websites), this group can be broken down into 116 actors who are primarily hardware and software producers and 1,497 application developers or designers and system integrators. General information was also collected about the enterprises themselves (primary and secondary locations in Germany, legal form, foundation year, number of employees).

In order to interview the industry players using the online survey, the email addresses of suitable contact persons (where possible at management/board level) were also identified and qualified by hand.

Research of the population was followed by the field phase with an online survey of the companies. The survey consisted of four thematic blocks to reflect the research questions:

- Information about the companies/organizations
- Business climate in the XR sector
- Activities in the digital ecosystems
- Metaverse

The identified XR companies were contacted at the researched email addresses and invited to participate in the standardized online survey in three survey waves between June 1 and July 4, 2022. Of the adjusted population, it was possible to contact 1,456 companies by email. Within this group, 224 people opened the survey and 221 began answering. 174 participants completed the first block of questions (general information about the company) in full, and 131 people answered the entire survey. This is equivalent to a response rate of approx. 8.9 percent. The average time to complete the survey was around 21 minutes. To ensure the quality of the data, participants were excluded who took a remarkably short time to complete the questionnaire (<2 minutes) along with those who consistently ticked the same thing in parts of the questionnaire (e.g. also inverted items). One participant was excluded for completing the questionnaire too quickly, while serial clicking was not an issue in the sample. The final survey sample was therefore n=130.

The response rate per segment differed slightly; for instance, the rate among companies with 11 to 50 employees was 22.3 percent. But this group accounts for 29.7 percent of the population. Accordingly, a weighting factor was applied to the responses based on the number of employees (target population/actual survey sample) in order to obtain a representative picture relative to the entire population. This means that the data of the weighted sample is, in addition, largely representative of the basic population with regard to the foundation time as well as the regional distribution of the enterprises (also and in particular with regard to the leading XR clusters in Germany). A direct comparison of the main focuses of activities (hard/software producers vs. application developers) is not possible due to the questions. However, it 'tends' to be true in this case that only a minority of the companies surveyed are predominantly active in the production of XR hardware/software or as system integrators *(cf. Chapter 3.2.).* It follows, therefore, that meaningful statements can be obtained on the basis of the weighted dataset.

Nearly 90 percent of the survey respondents are owners, managing partners, members of management or the board of directors. Around eight percent of the respondents are department/division managers or project/team leaders and only around two percent do not hold a management position *(cf. Table 1)*. The survey therefore reached persons who primarily work in senior hierarchical positions within the XR companies.

Table 1: Hierarchical positions of the respondents

Hierarchical positions of the respondents	Absolute frequencies	Percentage share
Owners/managing partners	**107**	**83.6%**
Members of the management board/directors	**7**	**5.5%**
Heads of department/division	**7**	**5.5%**
Team/project leaders	**4**	**3.1%**
Experts/employees without managerial remit	**3**	**2.3%**
Other purviews	**0**	**0.0%**

Source: Own data obtained by means of the representative online survey, n=128 (no data: n=2)

The respondents also hold extensive personal experience in the XR sector, with almost three-quarters (71.3%) of them possessing at least five years of experience in the XR sector; 14.7 percent of respondents have even been active in the XR sector for over ten years. An appraisal of the sector expertise reveals that just over half of the survey participants (52.3%) classify themselves as experts in virtual reality, almost a third (32.3%) describe themselves as augmented reality experts, and respondents in the smallest group (15.4%) have particular expertise in mixed reality.

2. DELIMITATION OF THE TERMS ‘EXTENDED/CROSS REALITY’

In order to delimit extended/cross reality (XR) in regard to its content, Milgram et al. created a first definition back in 1995, which can be used to classify the different forms of virtual and augmented reality in a continuum *(Milgram et al., 1995).* In his mixed reality scale, Saunter also described the space between reality and virtuality as a continuum *(Saunter, 2009),* in which the degree of immersion plays a central role in the distinction: Within virtual reality, immersion is the illusion of being part of a virtual world. By contrast, this immersion can only be experienced to a comparatively limited extent on the internet or in video games. Our distinction between the three sub-markets of virtual reality, mixed reality and augmented reality is also based on the degree of immersion. Whereas virtual reality users wear a head-mounted display that shields their vision completely from the environment, mixed reality users wear goggles that show visual information but allow a 'see through' into the real world. We define augmented reality to mean applications in which a device (usually a smartphone) is used to incorporate additional information on its screen as an overlay to the real world.

2.1. Technical Delimitation

The manner in which XR content is created and made experiential, or which properties are attributed to the media forms, depends heavily on the type of output device used. In principle, the following distinguishes between six types of output device *(cf. Table 2)*. We have slightly adapted the categories used in the previous year and include mobile VR and AR as separate ones in order to reflect advances in technology.

Table 2: Classes of XR output devices

Type of output device	Examples	Description
Low-end VR	Google Cardboard	Affordable entry-level virtual reality product that uses smartphones as the technology platform.
Mobile VR	Samsung Gear	Also use a smartphone or proprietary display as the basis, but also have their own sensors to transfer the movements of the head into the virtual world and offer an optimized user experience.
Full-feature VR	Oculus Quest	The headsets are connected to a high-end PC or gaming console to deliver an immersive experience of virtual worlds.
Mixed reality/ smart glasses	Nreal, HoloLens, Google Lens	Data glasses that show additional information relating to the environment in the user's field of vision.
Augmented reality	E.g. Pokémon Go, virtual fittings, etc.	Smartphone applications that overlay virtual information on the smartphone's camera image without requiring additional devices.
Projection-based solutions	Caves, workbenches, wall projections	Rear projection-based displays that are mainly used in research, 3D prototyping or the robotics industry.

Source: Own research

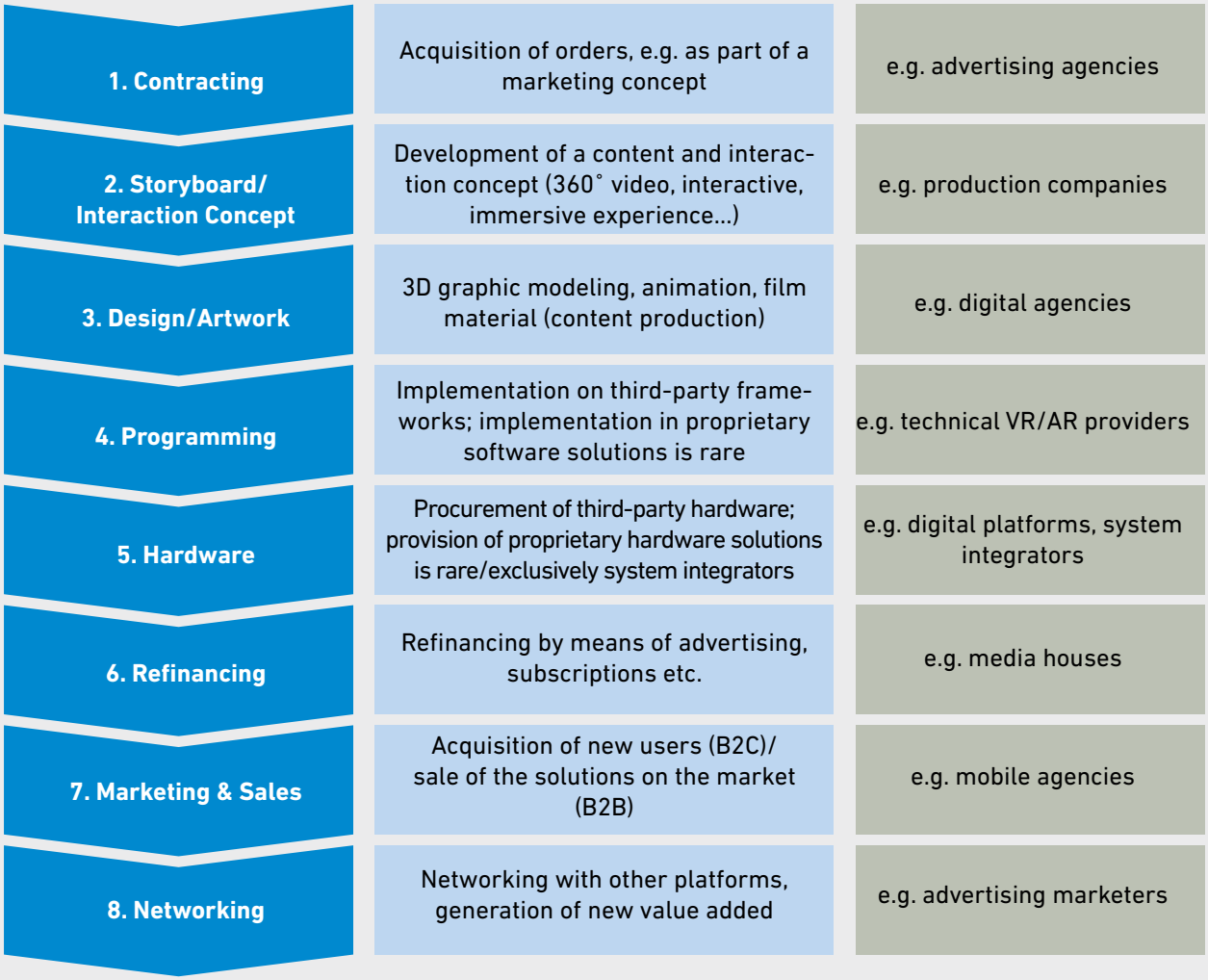
2.2. Industrial Economic Structure of the Sector

The XR sector describes a comprehensive ecosystem with numerous overlaps between the individual sub-sectors. For a more detailed examination, previous studies developed a breakdown of activities that allows vendors to be grouped according to their position within the value chain. This also enables differentiation of market-related target sectors and the content/functionalities offered. These distinctions will be outlined briefly in the following for reasons of comprehension.

2.2.1. Breakdown Based on the Value Chain

Companies operate at different stages of the value chain within the XR sector. The companies at the first stage of the value chain deal with the production of hardware, for example VR headsets, and/or the creation of the software (e.g. frameworks such as Unity). They are therefore vendors without whom the realization of XR projects would not be possible. Application developers and designers are found at further stages of the value chain, along with system integrators. They are developers and designers of XR applications, as well as vendors that integrate purchased hardware for which they develop applications. The value chain for projects within media production can be used to describe these activities. This is based on a perspective that covers the entire acquisition/production process *(cf. also the example of product development Berg & Vance, 2017: 11).* Finally, the provision of consultancy services to customers also constitutes a significant field of activity; this can take place at all stages of the value chain. The individual phases are then as follows *(cf. Figure 1):*

Figure 1: Value creation chains for XR projects



Source: Own research

By the time a contract is signed, an understanding of which issue requires a solution and the user's (customer's) value chain will typically have been established already. This is used as a basis to develop a storyboard for the planned application. A particular focus is placed on the interaction concept, which describes how immersive and interactive the experience should be. Implicitly, this also determines the downstream stages 3, 4 and 5. Complex 3D animations and models are generated when producing the artwork and design. The design is not focused exclusively on the look and feel of the content, but can also extend to the user interface.

Programming and hardware at stages 4 and 5 are frequently steps that can be outsourced or purchased directly. In this case, the system integration phase for the sub-steps (content, programming and hardware) acquires a particular significance. As presented here,

programming describes application programming that uses suitable frameworks for the purpose of implementation. Given that many XR applications are rolled out to end users free of charge, stage 6 of the value chain carries particular weight, as it deals with the issue of identifying refinancing opportunities, e.g. through integrated advertising or in-app purchases. Many forms offered in the B2B segment especially are custom builds, intended to resolve an issue that is specific to an individual customer, so designing the product to be suitable for resale is of considerable importance on the B2C and B2B markets. Connectivity with other services, platforms and offerings is the final stage in the value chain.

This study, like previous ones, also distinguishes between two principal activities among XR companies. Firstly there are producers of hardware and/or software, i.e. vendors that enable the realization of XR by providing the frameworks and/or hardware for the realization of XR applications. They should be placed at stages 4 and 5 of the value chain and only account for a small part of the XR sector as a whole. The second group of XR companies are developers and designers of XR applications, as well as system integrators, i.e. developers and designers of XR applications and vendors that integrate hardware and develop applications. These companies operate at all stages of the value chain for XR projects and represent the majority of providers.

2.2.2. Breakdown by Markets

Relevant literature currently distinguishes a number of core sectors in which XR offerings are used. They are presented in the following table. For the sake of clarity, manufacturing is grouped as one sector, although it encompasses a number of different sub-sectors (e.g. automotive, aviation).

Table 3: Target market content matrix for cross reality

	Target Market / XR applications/content	Medicine	Arts/architecture	Media	Advertising/marketing	Manufacturing	Tourism	Logistics	Live entertainment	Military
B2C	Information/Entertainment (e.g. news videos)	✓	✓	✓	✓		✓		✓	✓
B2B	Games	✓		✓	✓		✓		✓	
B2B	Navigation (e.g. wayfinding in logistics)		✓	✓		✓	✓	✓		✓
B2B	Product presentation (e.g. advertising, point of sale)		✓	✓	✓		✓			
B2B	Training (e.g. further training of employees, workflow induction)	✓				✓		✓		✓
B2B	Production/maintenance/service (e.g. support in the production process and customer contact)	✓				✓		✓		✓
B2B	Design/Simulation (e.g. prototype design)	✓	✓			✓				✓
B2B	Conferencing & collaboration (e.g. virtual conferences or collaboration)	✓				✓		✓		✓

Source: Illustration based on Zabel et al., 2021, p. 32

The individual sectors crop up to differing degrees in content offerings or application scenarios that can be implemented beneficially using XR. In essence, the distinguishing feature is whether they are intended for use in a B2B or B2C context, although a certain overlap is identifiable. The various content/application forms can be delimited as follows:

- **Information/Entertainment** This refers in particular to content produced by media providers, for instance 360° videos on current affairs. In this context, the New York Times was an early adopter, offering its subscribers a free Google Cardboard viewer that could be used to access published content. The area of entertainment encompasses the plethora of showcases, especially sporting events, in which widespread interest, personal investment and a willingness to pay are most likely to coincide *(Kunz & Santomier, 2019).* Concerts/ music represent another application area.
- At present, the 'killer applications' in the B2C segment are mainly **gaming** content. Sophisticated VR games for consoles and PCs *(Kunz et al., 2021)*, as well as smartphone-based applications, are all becoming increasingly popular, as evidenced by Pokémon Go *(Hamari et al., 2019).*
- **Navigation systems** that enable spatial orientation represent a third application form. Numerous consumer-oriented applications are available in this segment, e.g. in tourism as well as among live entertainment providers (museums, amusement parks, etc.). Logistics companies are also active in the B2B segment, alongside enterprises that are keen to optimize their internal warehousing/picking and to manage their flow of goods *(Lang et al., 2019).*
- Another hybrid use case that is of equal interest to consumers and business customers alike is the **design of product presentations.** This area has many use cases in the B2C market: They range from apps that allow users to position furniture in a virtual rendition of their homes, to mirrors that project possible outfits onto the customers and even the virtual presentation of a customer's new car at a trade show booth *(Peukert et al., 2019).* These use cases are naturally crucial in the areas of marketing & promotion, as well as for providers in the fields of arts & architecture.

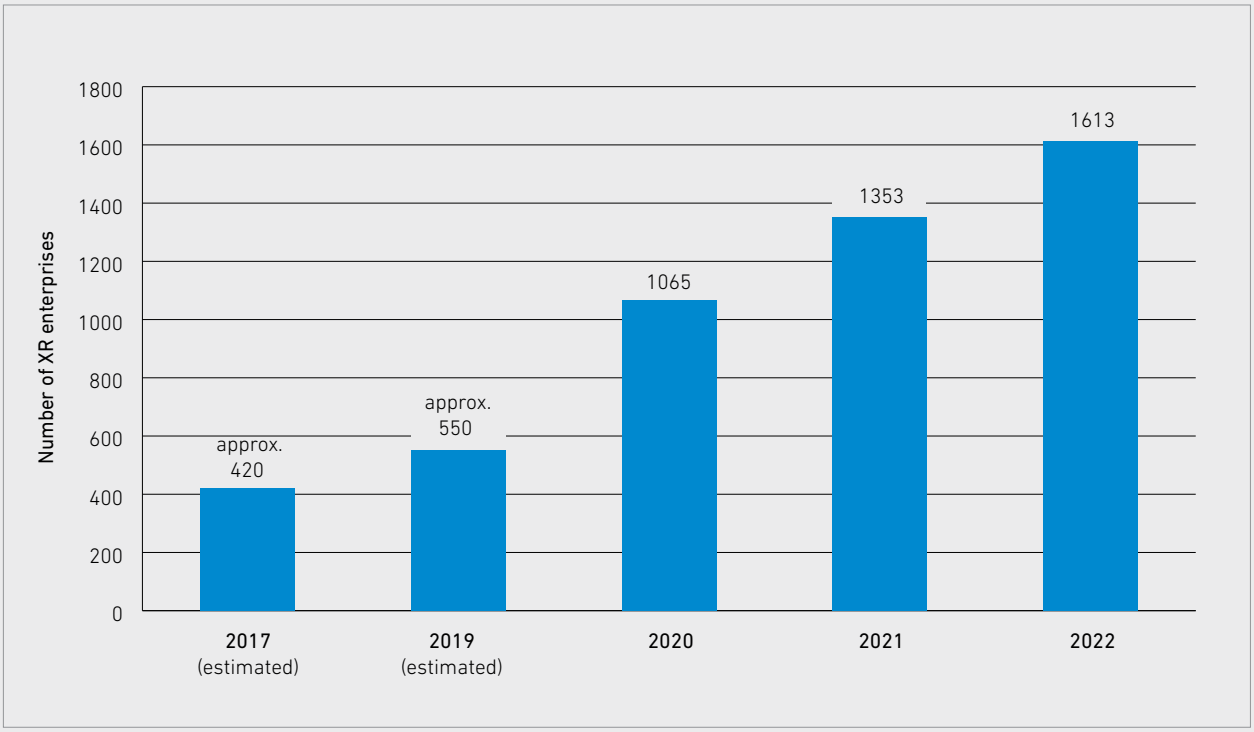
- In the area of **training**, XR enables course participants to complete simulations or to obtain additional information on specific subject matter *(Huang et al., 2010).* There is a particular need for this kind of application in the industrial sector, but also within medicine *(Zabel & Telkmann, 2021)* and the armed forces, as upstream simulation of such complex and potentially critical live situations offers significant advantages.
- Applications in the areas of **production/maintenance/service** follow the same logical principles: They are mainly concerned with using mixed and augmented reality as a means of optimizing workflows. In particular, a greater focus on information-assisted processing enables standardization of workflows that in turn ensures more collaborative completion *(Roth et al., 2015).*
- **Design and prototype manufacturing** is a specific category within the production process. Industrial enterprises and the scientific community can benefit significantly here *(Berg & Vance, 2017).* 'Artistic' applications would be conceivable as well.
- Finally, VR and MR applications in particular enable improved collaboration through **virtual conferences and collaborative work sessions.** This is certainly a very interesting aspect of XR against the backdrop of the COVID-19 pandemic and rising debates about the use of virtualization as a greener option for collaboration (less travel).

3. STRUCTURE OF THE XR SECTOR IN GERMANY

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

This year's survey identified a total of 1,613 companies in Germany that manufacture XR at one or more of the investigated stages of the value chain. In addition to startups and small to medium-sized enterprises, they also include departments within major corporations pursuing an independent XR strategy or offering services in this field. This means that there has been a sharp rise in the number of XR companies in Germany over the years. *(cf. Figure 2).*

Figure 2: Number of XR enterprises between 2017 and 2022



Source: Own data obtained by means of desk research; based on a projection of the XR enterprises researched in NRW for 2017 and 2019

Besides analysis of this population, the following evaluation is based on the n=130 online questionnaires that were completed, although the 'n' for the individual questions may vary slightly due to pairwise case exclusion. The following section reports the data for the population and for the representatively weighted survey sample. Moreover, the sectoral development – when meaningful – is compared with the trends over the previous years.

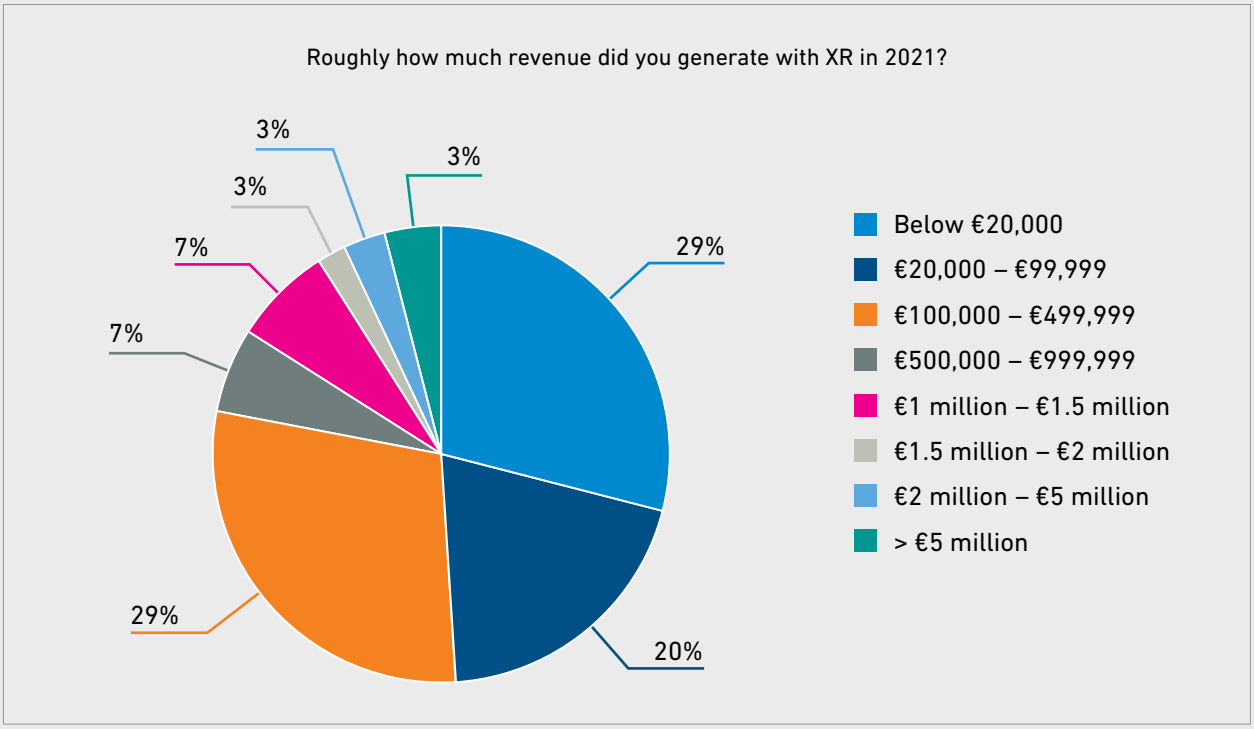
3.1. Revenue and Employment within the XR Sector

The companies were asked about their revenue structures and number of employees in order to be able to make statements about the overall economic relevance of the XR industry. In this context, companies were given the option to state last year's revenue with XR either directly (in euros) or according to intervals. As some companies only selected the second option, the revenue data in euros was suitably encoded to show the revenue structure in intervals *(cf. Figure 3).*

Overall, German XR companies are recording a highly positive revenue development. More than half of the XR enterprises are already generating over €100,000 in revenue (a three percent increase compared to last year's survey). 16 percent report revenue of more than €1 million with XR. This value has almost doubled year-on-year. A highly positive trend is also observed in the leading group: The share of companies with revenue of more than €2 million with XR grew year-on-year from two to six percent of companies.

The other half of the market (49%) consists of smaller enterprises that generate less than €100,000 in revenue with XR. They (93%) are primarily (small) enterprises with up to five XR employees. This is yet another confirmation that substantial revenues can already be generated with XR technology.

Figure 3: Revenue generated by XR companies with XR in 2021



Source: Own data obtained by means of the representative online survey (n=118, no data: n=12, outliers are unweighted)

An interesting factor is whether companies that focus primarily on XR differ strongly from other companies in regard to their revenues. For this purpose, the companies that stated in the survey that they are almost exclusively (>95%) or very strongly (>75% of the company activities) active in the XR segment were considered separately (n=51). These enterprises are referred to in the following as 'high XR' enterprises. They are able to generate larger XR revenues than 'low XR' enterprises that barely focus on XR (<25% of the activities focus on XR). For example, 22 percent of the 'high XR' enterprises generate more than €1 million with XR, while the equivalent number for 'low XR enterprises' is just 9 percent. At the same time, 72 percent of the 'low XR' enterprises generate less than €100,000 in revenue, while the same is true of just 40 percent in the 'high XR' segment.

The 'higher' revenue categories mainly consist of companies that offer proprietary hardware/software solutions as well and are not merely active as application developers. A comparison of companies with XR revenue of over and up to €100,000 confirms this assertion. While 63 percent of enterprises in the first group produce XR software at least in a smaller extent (and 28 percent manufacture XR hardware), only 43, i.e. 15 percent of companies with revenue of

up to €100,000 do so. Among firms with more than €1 million in revenue, 72 percent report some degree of software and 33 percent hardware production. These focal points of activity are therefore far more pronounced among companies with larger revenues.

The representatively weighted revenue data can also be used to estimate the cumulative revenue volume and also the scope of employment within the XR sector in Germany. Two methods were used to make the estimate. This was done to consider the potentially distorting effects of individual data items. The 'conservative' estimation model initially excluded from the calculation any values that showed a particularly strong deviation, either upwards or downwards, in the revenue:XR employee ratio. The remaining data (in regard to the distribution of identified employee intervals) was calculated representatively and an arithmetic mean obtained. This was then extrapolated to the totality of XR companies in Germany (less the number of eliminated 'outliers'). Finally, the previously excluded cases were added together, using the average value of the size class for each of the cases. The outlier values were treated in the same way in the 'progressive' scenario, which represents the upper limit of our estimate, but the values provided by the companies were used as a basis.

The values should be interpreted as gross revenue figures, as no question was asked about contributions to earnings or prorated upfront expenditures. For example, the purchase of materials (e.g., XR hardware) is presumably included in the listed projects, so it is likely that certain revenue shares are only 'passed on' to larger hardware/system vendors.

The number of XR employees was estimated as a second aspect, based on the same methodology. The ratio of XR employees to employees was used as a basis, as the total number was identifiable for the population and we had requested this information (as well as the number of XR employees). Correcting outlier values is of particular importance here, because the population also contains a number of (large) corporations.

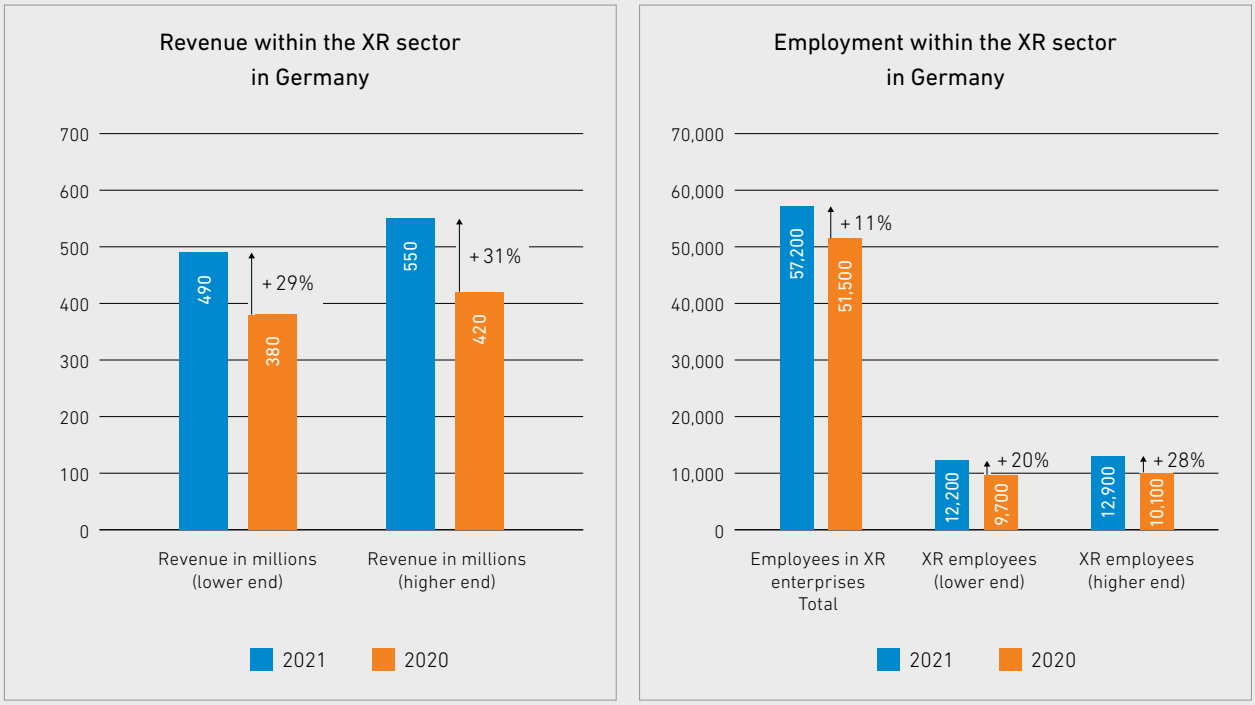
Our calculations show that German XR-producing companies generated estimated revenue of €490 to €550 million in 2021. The sector therefore recorded – despite COVID-19 – an impressive growth in revenue of around 30 percent. In terms of size, the German XR industry therefore ranks among other dynamically growing digital markets such as the local revenues of German games publishers or the revenues generated with influencer marketing in the DACH region [1].

[1] For example, the industry association Game estimated revenue on the German games market at €6.2 billion in 2019, whereby German games companies account for around 5% of the value creation. (Castendyk et al., 2021). Goldmedia estimated the market volume for German influencer marketing at €990 million in 2020 (Goldmedia, 2018).

Estimated at 10,000, the number of employees in the narrower games sector (development and publishing) possesses a similar magnitude as well *(cf. Figure 4):* We estimate the number of XR employees in 2021 at between 12,200 and 12,900 people. It is reasonable to assume that the wider industry (i.e. including marketing and sales of B2C-related XR products, but also employees in B2B user companies) is likely to be significantly larger than the core area analyzed here. The total number of employees working in the XR companies is therefore 57,200 people. This figure does not include the 44 companies with more than 1,000 employees, as larger corporate groups would have greatly increased the number. The employee figures for the surveyed companies >1,000 and <8,000 employees were added this year to compensate for this (the updated method was followed analogously for 2021, which is why the employee figures here may differ from last year's report).

This indicates that revenue in the XR industry is growing at a faster rate than the number of employees, namely at 30 percent (mean of the range: 24%). A growing significance of scale and platform effects is most likely the reason for this disproportionate growth. Moreover, it emphasizes the particularly vigorous growth in enterprises generating more than €1 million in revenue with XR. This almost twofold increase in the size of this group in comparison to 2021 may be due to an progressive shift from offering individual applications ('contract manufacturing') to scalable software and hardware that is distributed via platforms. At the same time, the growing prevalence of standards and frameworks may increase productivity so that XR offerings can be produced with greater resource efficiency. Finally, the smaller increase in employment in XR companies overall (+11%), combined with the higher increase in XR employees, points to a reallocation of current human resources towards XR.

Figure 4: Revenue and employment within the XR Sector



Source: Projection obtained by means of the representative online survey.
** = Value for 2021 may deviate from the previous year's report due to the adjustment in the survey methodology.*

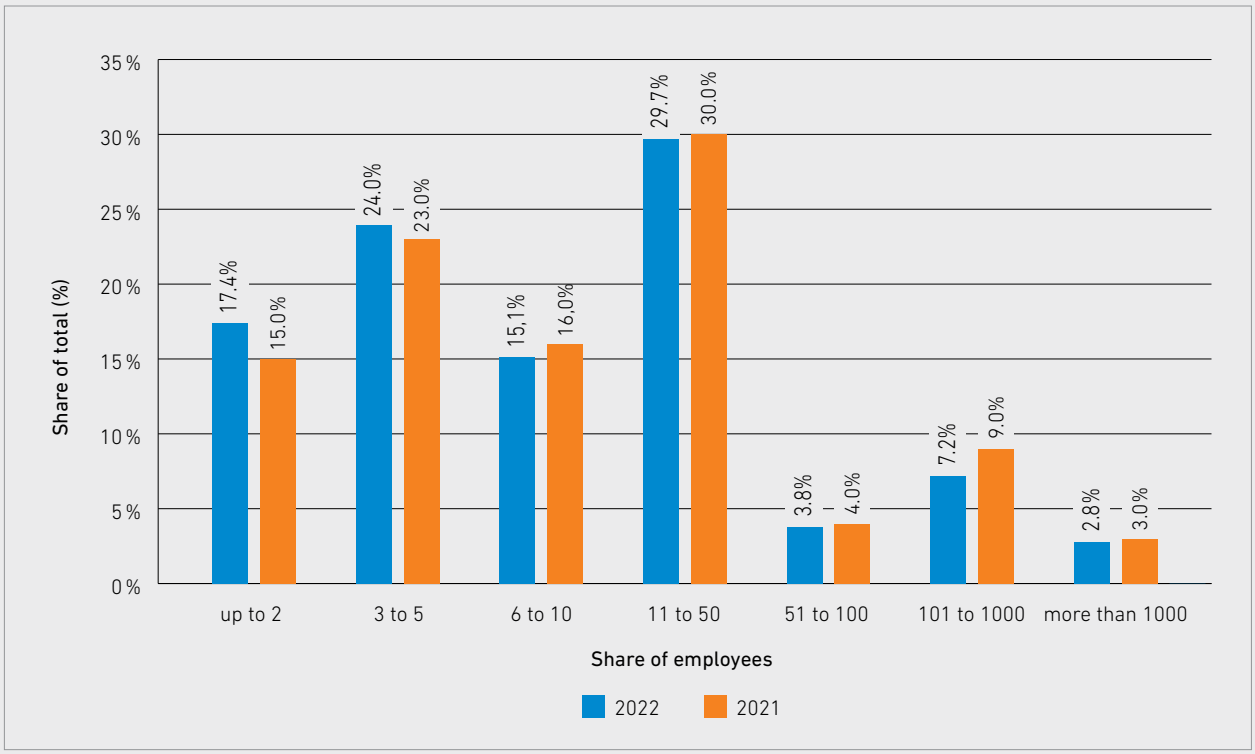
Looking at overall productivity in the XR industry based on these figures, it appears that the industry generates on average between €40,200 and €42,600 in XR revenue per employee. This is more than last year, when the range was between €39,200 and €41,600. A more detailed breakdown would not be meaningful at this point due to the data quality; this should be differentiated more precisely in future studies (e.g. breakdown by employment type and activity).

3.2. Size and Age of the XR Companies

In addition to the overall view, a nuanced examination of the sector's structure is also revealing. A first step is to consider the size of the companies, operationalized in this case according to the number of employees. It was not possible to research any information on employee numbers for 1,544 of the 1,613 companies. But it becomes clear nonetheless that over half of the XR segment (56.6%) is composed of companies with up to ten employees, while almost every third company (29.7%) has between 11 and 50 employees. Large SMEs are found

alongside corporations as well, although they tend to be the exception. Only 10 percent of the XR companies have more than 100 employees. Structurally speaking, the share of smaller companies in terms of employees has experienced a slight increase compared to the previous year *(cf. Figure 5)*. This points to vigorous start-up activity, but also to the continuing entry of smaller companies into the XR market – relevant reasons may include lowered barriers to entry or favorable market prospects.

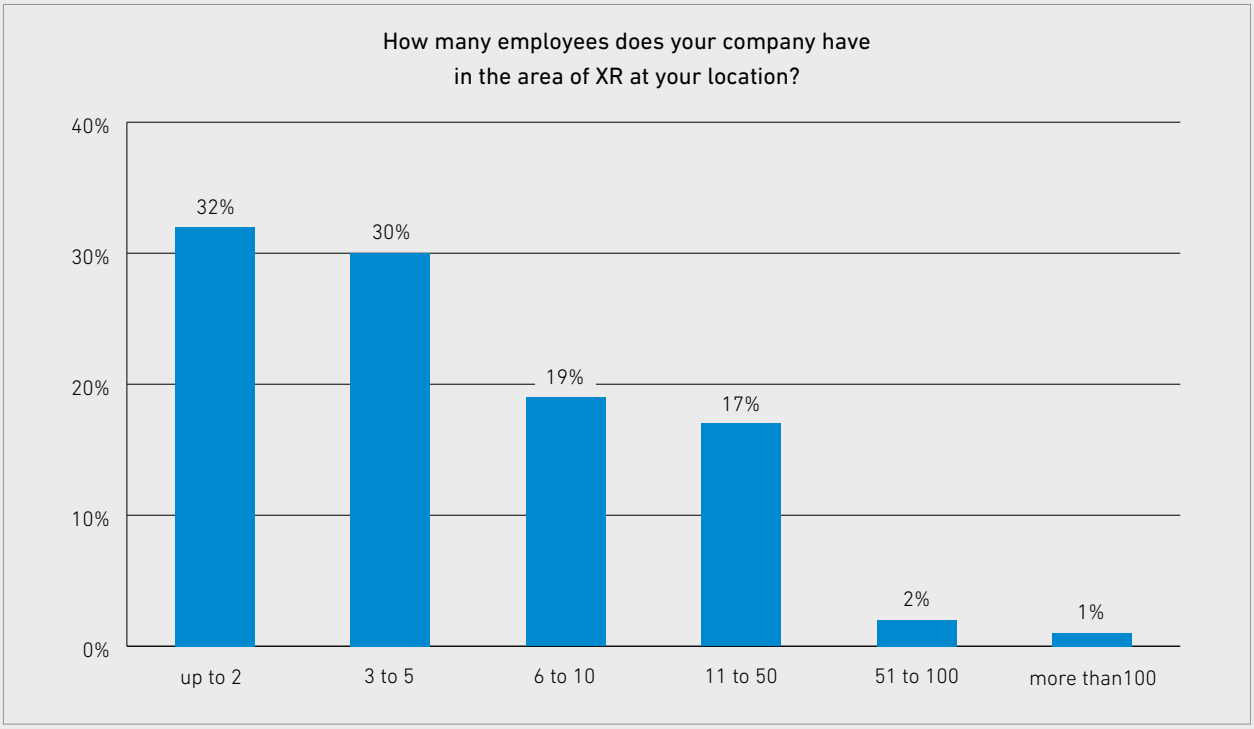
Figure 5: Distribution of XR companies according to size classes



Source: Own data obtained by means of desk research (n=1,544; no data: n=69)

Additionally, the online survey inquired as to the number of employees working on XR topics at each location *(cf. Figure 6)*. This appears purposeful, especially in regard to the (large) companies, in which XR only accounts for a fraction of their overall activities. The responses indicate – like in the studies over previous years – that predominantly smaller teams work in the area of XR. 37 percent of the surveyed companies reported having up to 2 XR employees. But the respectable number of every fifth company had between six and ten XR employees and another fifth even had at least eleven employees in this area. This includes the 3 percent of enterprises with more than 50 XR employees.

Figure 6: Number of employees in the area of XR



Source: Own data obtained by means of the representative online survey (n=128, no data: n=2)

A separate consideration of high XR companies is equally revealing in regard to the number of employees. It is noticeable that the companies with a strong focus on XR tend to be smaller (72.5% have up to ten employees in total vs. 56.5% for all companies). A reason for this may be that these enterprises are considerably younger than those otherwise operating in the XR market (see below). At the same time, companies with a strong XR focus are slightly more likely to have more than employees (21.6% vs. 19.1% for all surveyed companies).

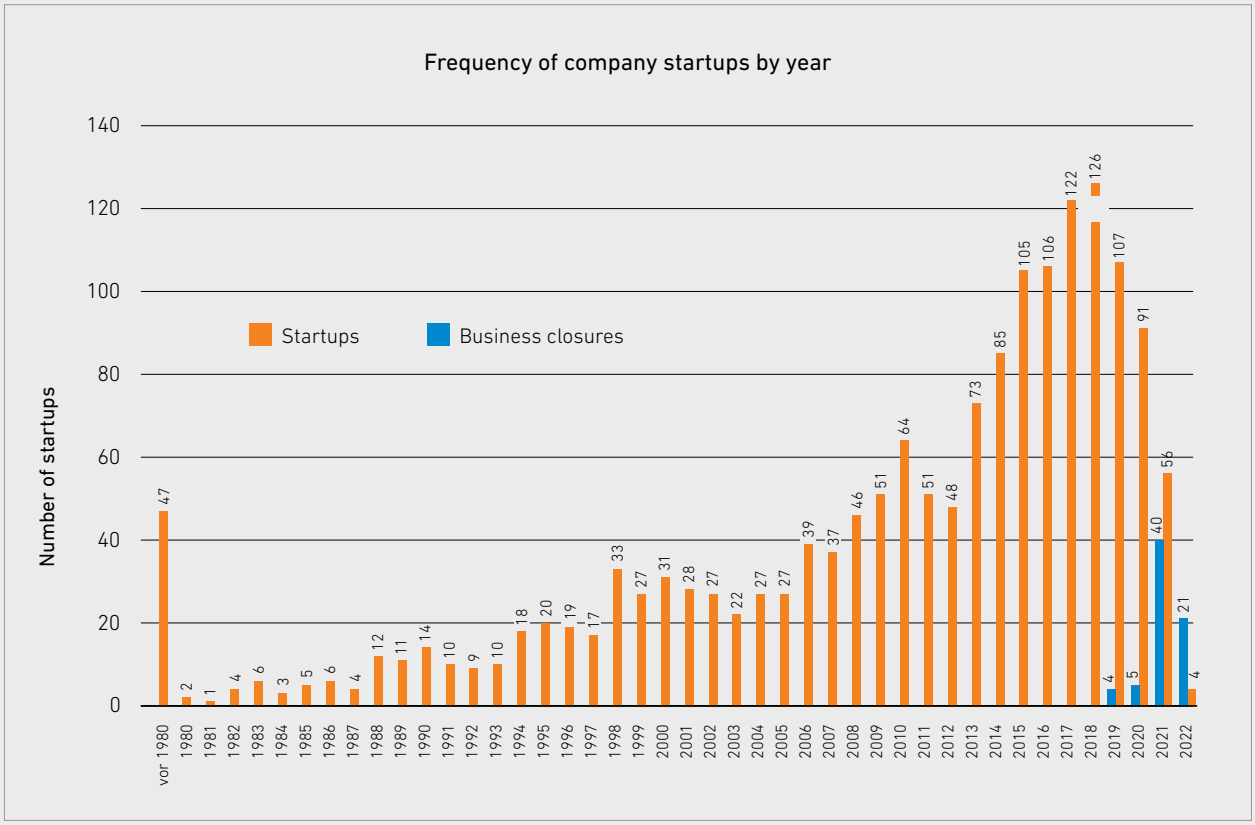
Aside from the company sizes, this study again investigated the times at which the XR enterprises were founded. The strong momentum recorded since 2015 has continued *(cf. Figure 7):* On average, just under 98 companies were founded each year in the area of XR between 2015 and 2021. 43.3% of all XR companies were therefore established within this period. By contrast, only 25.7% of the companies in the population were founded in the seven years before (2008–2014).

As in the previous surveys, the low(er) figures for 2021 and 2022 are due to the survey methodology. For instance, newly established companies may not yet have built a suitable web presence and are more difficult to identify using the search method. These numbers then

rise in subsequent years: For instance, our 2021 study identified 60 enterprises that were founded in 2020. By contrast, we have already found 91 enterprises this year for 2020.

The vigorous start-up activity is all the more pleasing if one considers that significantly fewer enterprises were forced to discontinue business operations. This will also be reported for the first time this year for 2019 onwards: In total, just 70 companies exited the market during this period. This means that the number of company startups each year outstrips the number of company closures by a factor of more than four, despite the extraordinarily challenging circumstances of the COVID-19 pandemic.

Figure 7: Foundation dates of the XR companies



Source: Own data obtained by means of desk research (n=1,611, no data: n=2)

Among the results of the vigorous startup activity is the young average age of the enterprises in the population. A good 52 percent of the companies are no more than ten years old. A renewed appraisal of the 'high XR' enterprises reveals that they are even younger by a considerable margin. All of them were established after 1990, most (92%) after 2000 and

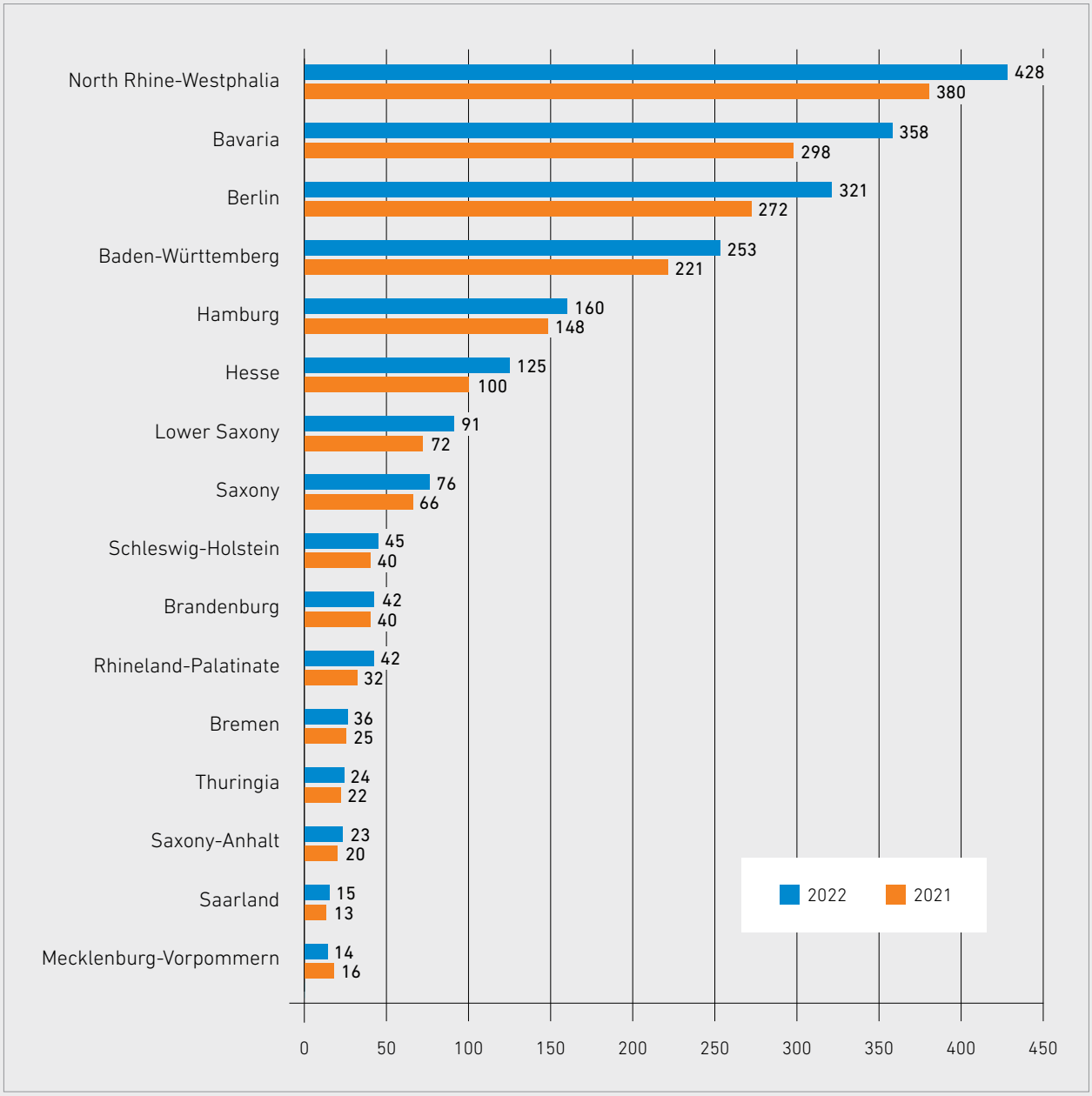
even the majority (51%) later than 2017. These enterprises have an average age of seven years (compared to 15 years for all surveyed companies and 13.5 years for the population). Moreover, merely 29.4 percent of these XR-focussed enterprises did not establish an XR division directly during their foundation. This was the case for 55.2 percent according to the representative survey.

3.3. Regional Structure of the XR Sector

The studies in previous years have shown that the regional distribution of the German XR sector varies strongly. This impression is confirmed by the current survey as well. Of the 1,613 companies, over 430 enterprises have secondary locations, which raised the total number of company sites to 2,043. The number of enterprises therefore grew by 19 percent, and the cumulative number of locations by 15 percent.

Most XR companies are located in a small number of states, with the top five states accounting for nearly three-quarters (74.4%) of all 2,043 company locations *(cf. Figure 8).* North Rhine-Westphalia has the lion's share of XR company locations (primary and secondary locations), namely 428. This is followed by Bavaria (358), Berlin (321), Baden-Württemberg (253) and Hamburg (160). All federal states – with the exception of Mecklenburg-Vorpommern – were able to grow their XR sector compared to last year. Growth was particularly dynamic in Bavaria (+60 locations), Berlin (+49 locations) and North Rhine-Westphalia (+48 locations); however, Hesse (+25%) and Lower Saxony (+26%) have seen the strongest rise in percentage terms.

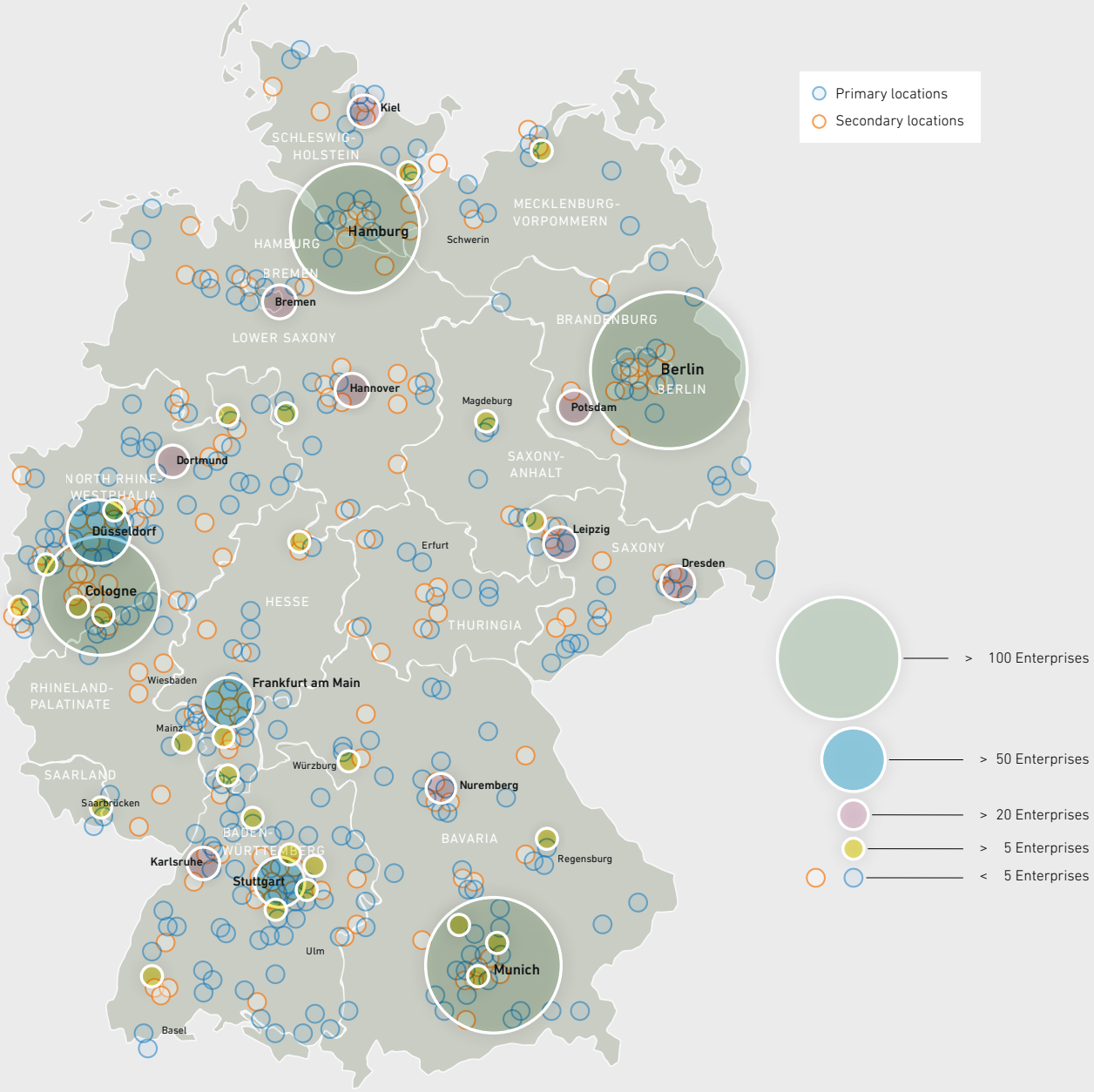
Figure 8: XR company locations (primary and secondary locations) according to federal states



Source: Own data obtained by means of desk research (n=2,043)

There is also strong regional differentiation within the federal states themselves *(cf. Figure 9)*. There are now quite a few locations with a sufficiently large number of XR companies, which enables local or regional networking advantages, in principle at least.

Figure 9: Regional distribution of XR companies (primary and secondary locations)



Source: Own data
obtained by means of desk research, n=2,043

A respectable 16 German cities now have more than 20 XR enterprises (primary locations or secondary locations). Just 13 cities reached this mark last year. If the largest XR agglomerations are considered, Berlin has 321 XR primary/secondary locations and is therefore ahead of Munich (n=181), Hamburg (n=160), Cologne (n=128) and Düsseldorf (n=71, *cf. Table 4).*

The top 4 account for 38.6 percent of all company locations with 790 primary and secondary sites. 38.9 percent of the establishments were situated in the top four cities last year. It follows, therefore, that the growth (in regard to locations) is evenly distributed across large and also smaller locations.

Table 4: Cities with more than 20 XR company branches

City	Number of XR companies (primary and secondary locations)
Berlin	321
Munich	181
Hamburg	160
Cologne	128
Düsseldorf	71
Stuttgart	61
Frankfurt am Main	44
Hannover	32
Nuremberg	29
Leipzig	28
Bremen	26
Dresden	25
Potsdam	23
Dortmund	23
Karlsruhe	22
Kiel	20

Source: Own data obtained by means of desk research (n=2,043)

The cities with the largest number of XR enterprises are easily visible as clusters on the map of Germany for the regional distribution of XR companies. Also of interest is the question of whether and where clusters of firms emerge with a focus on commercial XR activity ('high XR' enterprises). In our survey, the locations with several of these enterprises are Berlin (n=6), Munich (n=5), Hamburg (n=5) and Cologne (n=4). But it is equally clear that 'high XR' companies are found dispersed throughout Germany, in both larger and smaller cities.

After examining the German XR sector as a whole, the next step is to consider the number, size and founding dates of XR companies in the four leading German XR clusters, i.e. for Berlin, Hamburg, Munich and Cologne *(cf. Table 5)*. Only the primary locations are taken into consideration for calculating the number of employees. It follows, therefore, that the number deviates from the above values that included primary and secondary locations. In regard to the number of primary locations in the four urban centers, it is clear that Munich (+25.4% year-on-year) and Cologne (+23.4%) experienced particularly strong growth. Nevertheless, Berlin and Hamburg are reporting double-digit growth rates as well.

Table 5: XR companies in Cologne, Berlin, Hamburg and Munich

		Cologne	Berlin	Hamburg	Munich
Primary locations of XR companies (change compared to last year)		**101** (+23.2%)	**259** (+18.8%)	**123** (+11.8%)	**133** (+25.4%)
Number of employees at the XR companies	1-2	14.0%	20.3%	22.7%	15.1%
	3-5	24.0%	26.4%	24.3%	23.0%
	6-10	18.0%	11.8%	19.3%	13.5%
	11-50	31.0%	30.5%	28.6%	27.0%
	51-100	2.0%	2.9%	1.7%	6.3%
	More than 100	11.0%	8.1%	3.4%	15.1%
Founding years	Before 2000	22.0%	11.0%	7.6%	15.9%
	2000-2010	27.0%	25.6%	29.4%	31.9%
	2011-2015	31.0%	21.5%	26.8%	23.0%
	2016-2022	20.0%	41.9%	36.1%	30.2%

Source: Own data obtained by means of desk research (n=616)

The locations differ in regard to the structure of their XR sector in a number of respects. Cologne and Munich, for instance, have proportionately more larger XR enterprises. This is especially pronounced in Munich, where a good fifth of XR companies (21.4%) have more

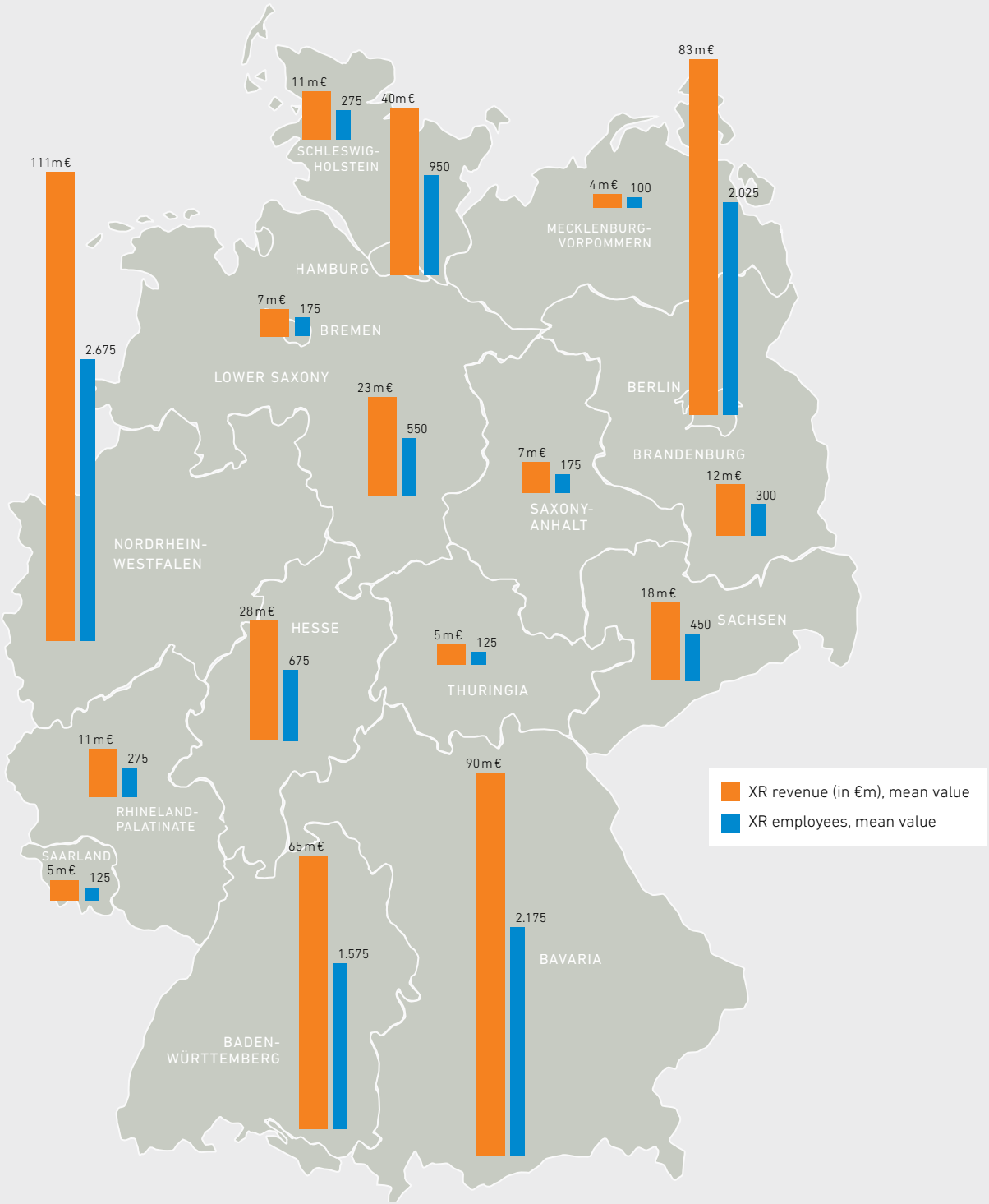
than 50 employees. By contrast, Berlin (47.1%) and Hamburg (47.0%) have a particularly high proportion of micro-enterprises (with up to 5 employees). There have only been slight changes year-on-year.

With regard to the foundation times, it is important to take into account that many enterprises added XR to their portfolio later on and have been included in the statistics since then. This leads, for example, to the fact that, compared to last year, 3.4% more firms were founded in Munich in the period prior to 2010. In any case, business startups after 2016 account for a higher share in Berlin (41.9%) and Hamburg (36.1%) than in Cologne or Munich.

The regional distribution of value creation was then examined. The case numbers that are based on the revenue and employment calculations for all of Germany mean that it is only possible at this point to make estimates for the individual federal states, as the details for individual XR enterprises may otherwise cause distortion. In this consideration, the individual regional sector structures were taken into account in regard to the number of primary locations. However, a more detailed breakdown (e.g. according to type of offering and employee numbers) was not possible due to the case numbers.

The regional breakdown shows that North Rhine-Westphalia ranks first in terms of XR revenue (between €104–117 million; mean value of the two estimated ranges: €111 million) as well as in regard to the associated number of XR employees (between 2,600 and 2,750 XR employees; mean value: 2,675). Following in second and third place are the federal states of Bavaria and Berlin. Both of these locations are close to each other in terms of their revenue and number of XR employees (Bavaria: €90 million in revenue with 2,175 XR employees; Berlin: €83 million in revenue with 2,015 XR employees). Coming in fourth and fifth are Baden-Württemberg (€65 million in revenue; 1,575 XR employees) and Hamburg (€40 million; 925 XR employees). The values in parentheses are the mean values of the upper and lower estimation ranges, respectively. They are also used in the illustration for the other federal states *(cf. Figure 10)*.

Figure 10: Regional distribution of extrapolated XR revenue and employees

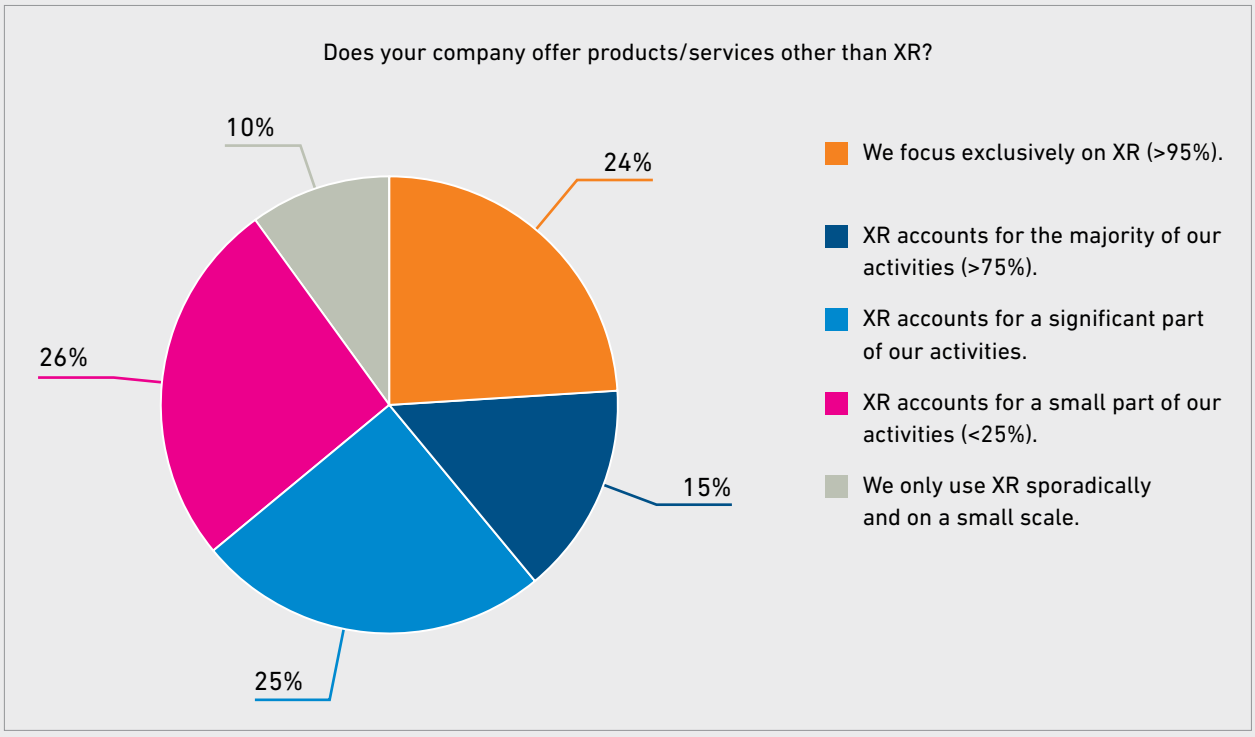


Source: Projection obtained by means of the survey and estimation models.
For better legibility, only the mean values of the two estimation ranges are stated.

3.4. XR Company Portfolios

Evaluation of the population demonstrated that many companies are engaged in activities other than XR. To obtain a more detailed impression, the companies were asked to state to what degree they focus on XR *(cf. Figure 11)*. XR is the principal field of operation for two of five companies (39%), accounting for at least 75 percent of corporate activities. Another quarter describe XR as a significant field of operation (at least 50%). However, 36 percent perceive XR merely as one topic among several; in this group, respondents estimate the share of activity in the area of XR at a maximum of 25 percent. These firms may include advertising agencies that have developed AR applications for specific customers but otherwise market a broad spectrum of digital services.

Figure 11: XR focus in the company activities



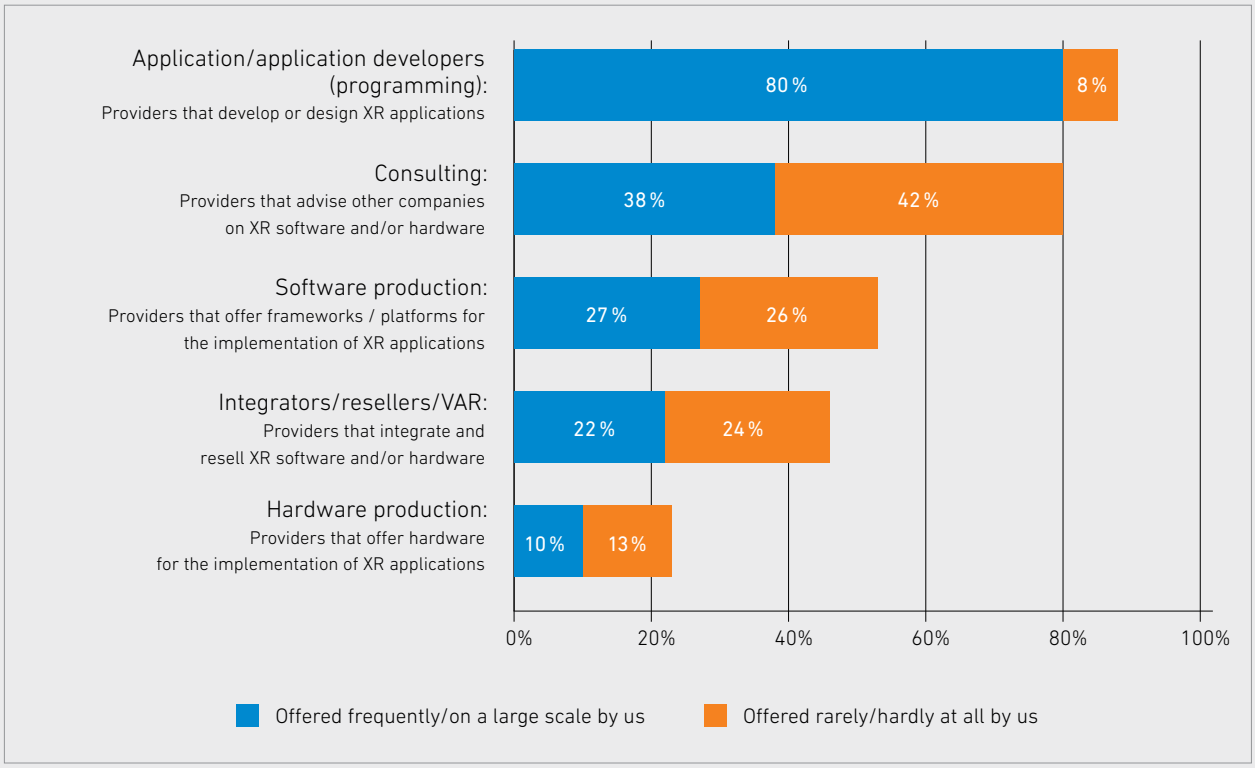
Source: Own data obtained by means of the representative online survey (n=128, no data: n=2)

This survey inquired not only about the relative significance of XR activities, but also which activities these are. Various groups of actors may be involved here, as explained in *Chapter 2.2.1.*: Producers of hardware and software used to make XR applications; application

developers and designers; system integrators as well as consultants who support users in the deployment of XR.

Last year's survey demonstrated that there may be overlaps in the company data in response to this question. Companies were therefore invited this year to state whether they offer corresponding services frequently, rarely or not at all *(cf. Figure 12).* As expected, most of the respondents classify themselves as application developers (80% frequently/on a large scale). Consulting services are also widespread, with 38 percent offering them frequently and a further 42 percent at least occasionally. By contrast, only 10 percent of the suppliers described themselves as producers of XR hardware on a large scale. The larger share of 27 percent in the XR software segment may reflect the attempts of the local XR industry to build independent scalable platforms, for example for the distribution of XR applications and content. A significant proportion of the enterprises operate also as software resellers or integrators (22% frequently/24% rarely), which is hardly surprising given the high technological fragmentation and development.

Figure 12: XR company purviews



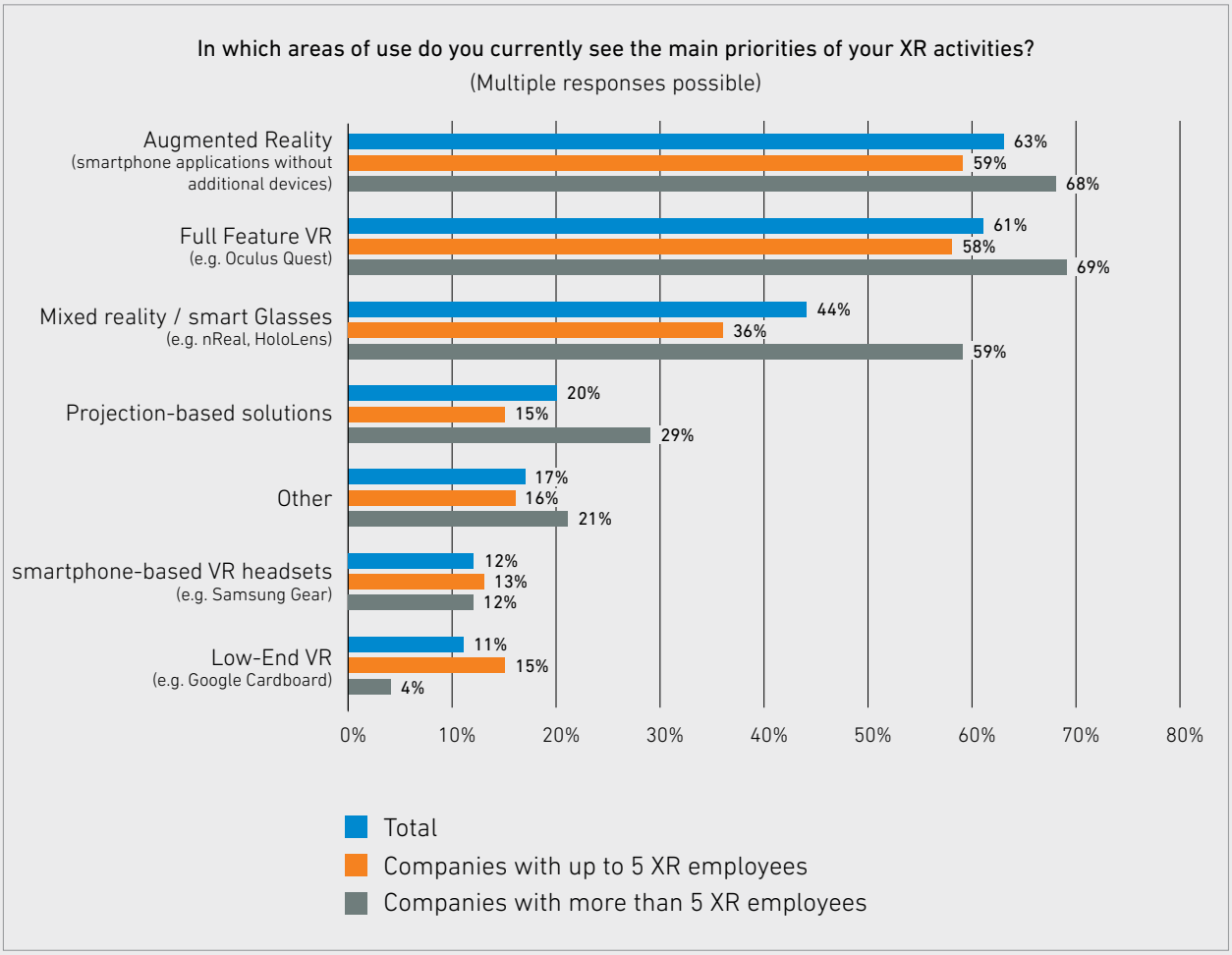
Source: Own data obtained by means of the representative online survey (n=114, no data: n=16)

Most of the 'high XR' enterprises also see themselves as app and application developers (82% frequently/4% rarely), as well as consultants (39% frequently/37% rarely), which is a slightly greater frequency than in the sector as a whole. They are, overall, somewhat more frequently active as integrators/resellers (22% frequently/31% rarely), but there are otherwise no major differences compared to the population of XR enterprises.

A consideration of the technical categories of XR that are predominantly used provides an even better impression of activities within the XR sector *(cf. Figure 13)*. The applications by most of the surveyed companies build on the augmented reality via smartphone category (63%/+0%) and full-feature VR (61%/-2% compared to 2021). Mixed reality/smart glasses follows in third place, accounting for 44%, which is a year-on-year decline (2021: 48%). Comparatively few companies define mobile VR (12%) and low-end VR (11%) as their priority. Presumably this reflects the continuously widening technological gap compared to the high-end device categories. Proportionate use is down 13 percentage points (mobile VR) and 4 percentage points (low-end VR) from the previous year. Every fifth company named project-based solutions as relevant XR categories, a slight rise compared to last year (2021: 17%). 17 percent stated additionally that they use 'other' output systems that may not be linked to any specific category. They may include, for instance, Web 3D, holograms, video training or the metaverse.

Viewed overall, a relatively large number of the surveyed XR enterprises use various classes of output devices. Just under 68 percent mentioned at least two categories. The companies specializing in one category focus mainly on full-feature VR (49%) and smartphone-based AR (28%). Only sight variations become apparent if these priorities are placed in relation to the company sizes. Mixed reality and projection-based solutions are particularly relevant for companies with more XR employees, which underscores the particular challenges of these categories *(cf. Figure 13)*. Smaller enterprises are more likely to use low-end VR (15%), which barely features at all among companies with over 5 XR employees (4%).

Figure 13: Focus of offerings according to output devices

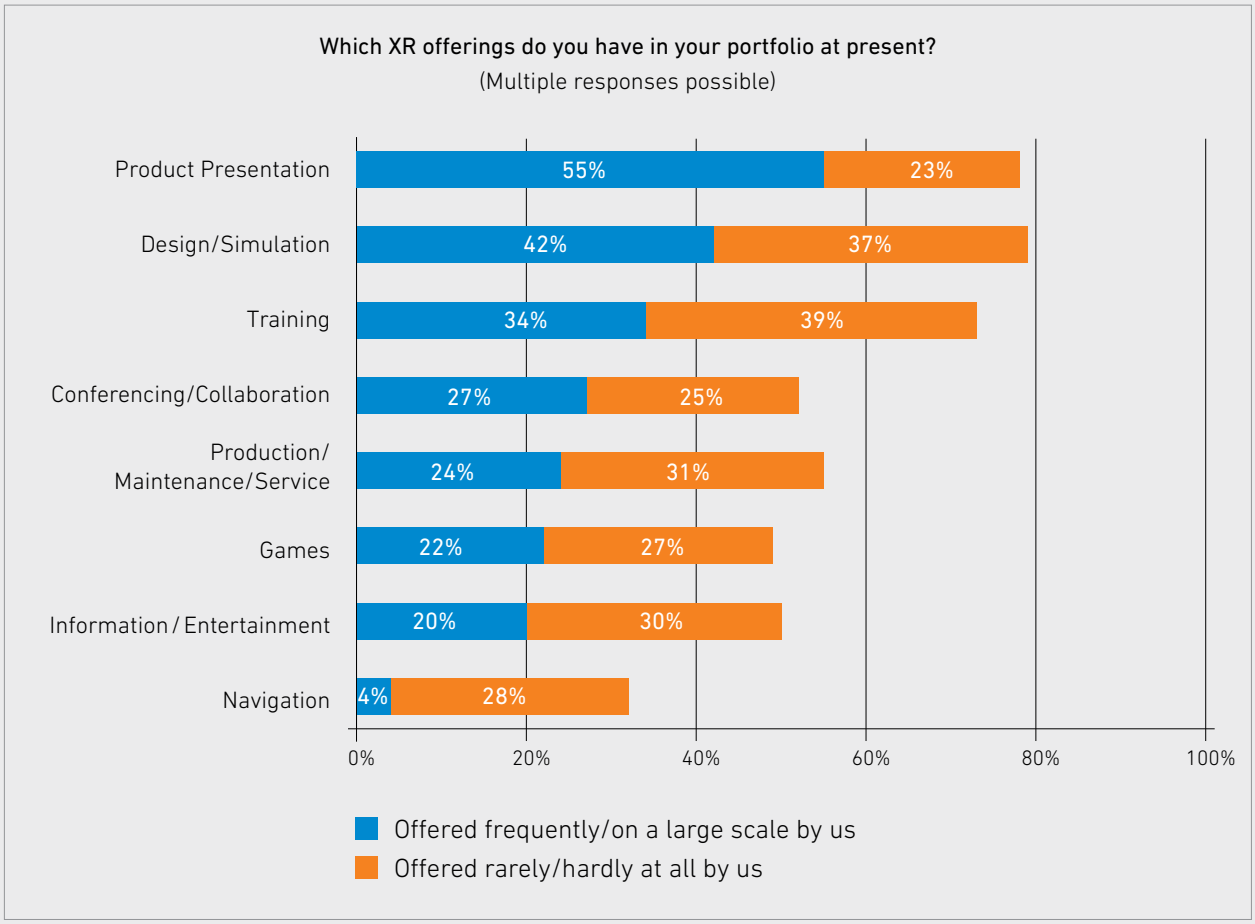


Source: Own data obtained by means of the representative online survey (n=130; companies with up to 5 XR employees: n=80; companies with more than 5 XR employees: n=48: no data: n=2)

In addition to the technical XR system categories, the survey also inquired about the specific services that XR enterprises offer. Here, product presentations are frequently offered by 55 percent of the companies, while 23 percent are at least rarely active in this field *(cf. Figure 14)*. Employment involving this kind of service has increased overall by two percentage points compared to 2021. This is followed by design and simulation (79% at least rarely/+11% compared to the 2021 survey), XR training (73%/+2%), production/maintenance/service (55%/+1%) and conferencing/collaboration (52%/-5%). The decline in virtual collaboration solutions may be explained by the 'end' of the COVID-19 pandemic – at least the current lifting of lockdown measures – which might have impacted the need for action and demand. The number of companies mentioning information/entertainment has also declined (50%/-7%).

This is probably also due to the fact that games (including serious games) were reported as a separate service category for the first time in 2022 – nonetheless, one in five companies is frequently active in this area and one in four (27%) is at least rarely active. But enterprises in both the AR and VR segments believe that the information and entertainment sector will show little potential for growth over the next 18 months *(cf. Chapter 5).* This value is likely to continue its downward trajectory going forward. Broadly speaking, there is a consistent trend for slightly more companies to offer a category on an infrequent scale compared to those that do so frequently or on a large scale. Exceptions to this are product presentations; the surveyed companies predominantly offer this category frequently (55% frequently vs. 23% rarely), as well as the category of navigation, which is predominantly offered rarely (4% vs. 28%).

Figure 14: XR company offerings



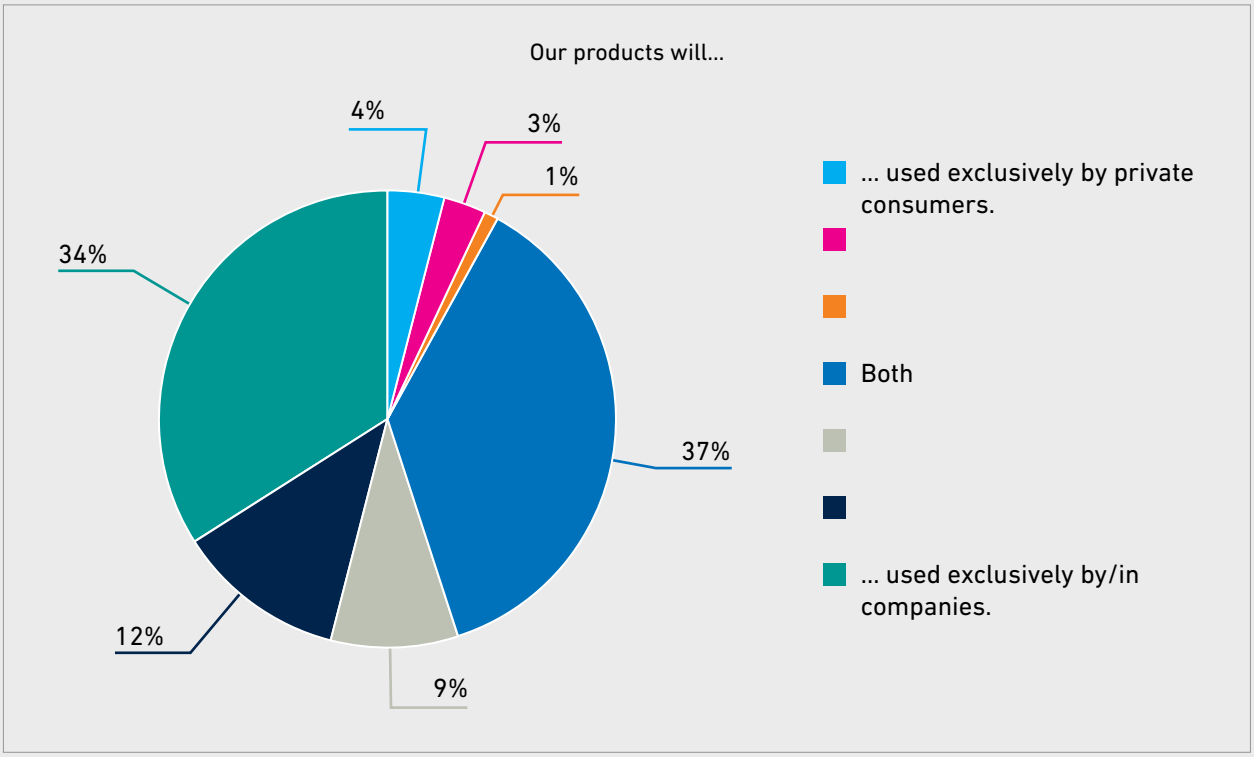
Source: Own data obtained by means of the representative online survey (n=122; no data: n=8)

Distribution is largely identical to the representative survey among the companies that build predominantly on XR ('high XR' enterprises); the values deviate only slightly. Only the number of high XR enterprises mentioning production/maintenance/service as a frequent offering is seven percentage higher and therefore a key offering; 34 instead of 27 percent of the high XR companies are also frequent providers of conferencing solutions. 'High XR' enterprises are less likely to offer product presentations (41% vs. 55%).

3.5. Customer Structure among the XR Companies

At present, the XR market in Germany is primarily a B2B market that aims at the deployment of XR by professional users, e.g. in companies *(Zabel et al., 2021)*. When asked about the focus of their XR activities, the majority of companies said they work predominantly or exclusively for B2B customers *(cf. Figure 15).* Only eight percent of the companies stated they operate mainly in the B2C segment. The number was five percent last year. However, a good third of the companies stated that they target both markets. This most likely includes cases in which the XR company develops an XR application aimed at consumers of a B2B customer (e.g. a furniture configurator for a furniture store that is used by consumers).

Figure 15: B2B and B2C focus among the XR companies

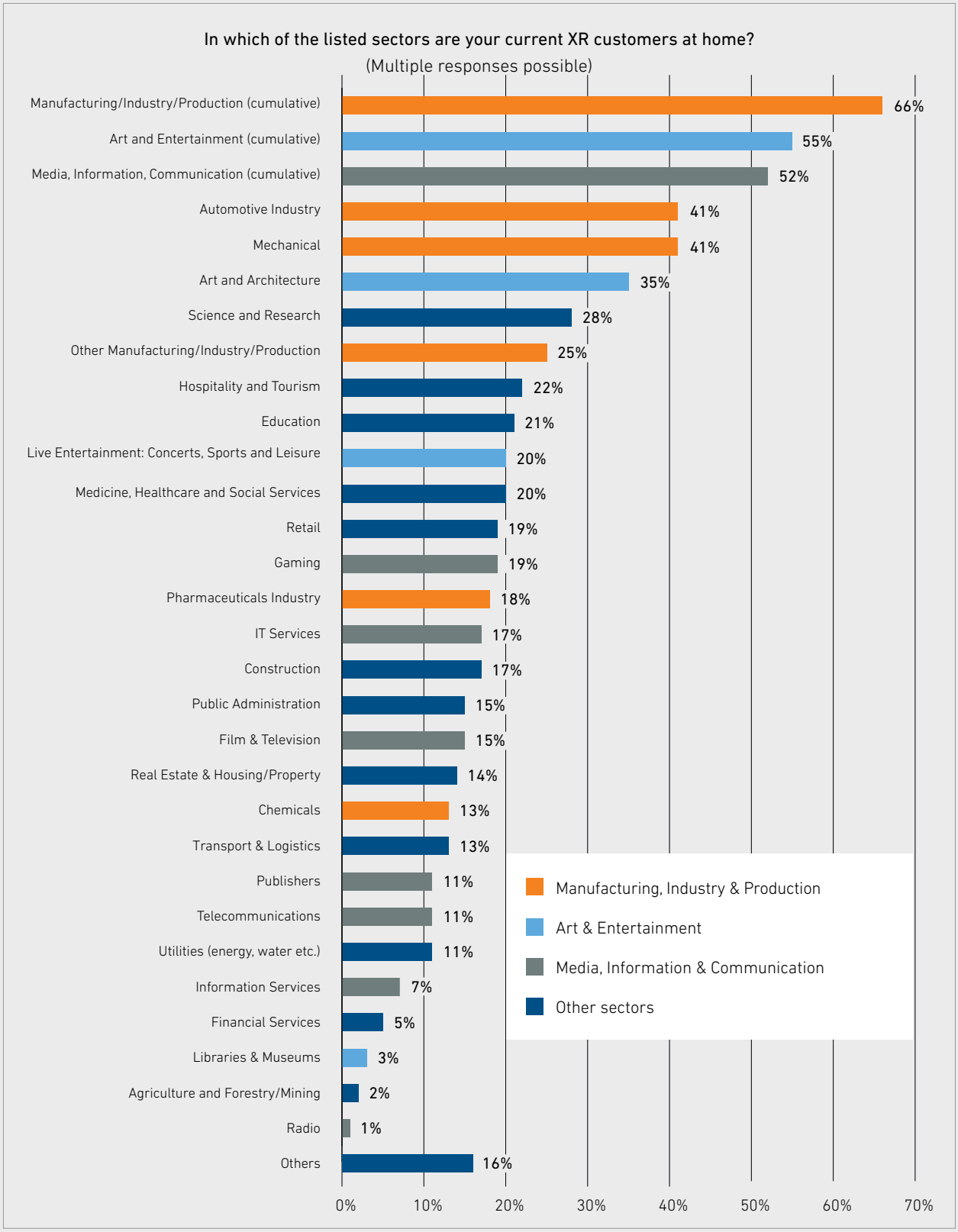


Source: Own data obtained by means of the representative online survey (n=130)

Overall, though, a clear focus on the B2B market is evident among German XR enterprises. The corporate customers are at home in a wide variety of sectors. The XR enterprises generally tend to operate across broad swathes of the market: 86 percent of the companies surveyed said they work for customers from several sectors. Merely 14 percent are focused on one sector alone. An XR company serves customers from five different target sectors on average (the classification of sectors follows the branches of industry defined by the *Federal Statistical Office (2008)).* Manufacturing is the most significant among them – 66 percent of the companies stated that they work for customers in this area. Here, the automotive industry (41%) and mechanical engineering (41%) are very important segments. Following in second place – viewed cumulatively – is the arts and entertainment segment (55%) – especially in the field of art and architecture (35%), although it also encompasses providers of live entertainment (20%). The area of media, information and communication (MIC, 52%) comes third (from a cumulative perspective). This aggregate includes gaming (19%) and the IT services sector (17%) on the one hand, although traditional media companies such as film and TV companies (15%) and publishers (11%) are among the customers as well. These aggregated

sectors are followed by individual ones, although they are mentioned quite frequently, also. For instance, just over every fourth XR company lists science and research among their customer segments. Hospitality and tourism (22%) are also relevant for more than one in five XR companies *(cf. Figure 16).* The order of companies according to the frequency of their mentions is comparable with the data acquired in the previous year, which suggests a certain degree of stability here. But it is noticeable that the sectors are mentioned somewhat less frequently overall: For instance, manufacturing 'loses' two percentage points, while retail is down five and the pharmaceutical industry four. By contrast, media-related customer sectors have made gains in particular: MIC rose by nine percentage points and gaming by eight (from a low baseline).

Figure 16: Target sectors of the XR companies

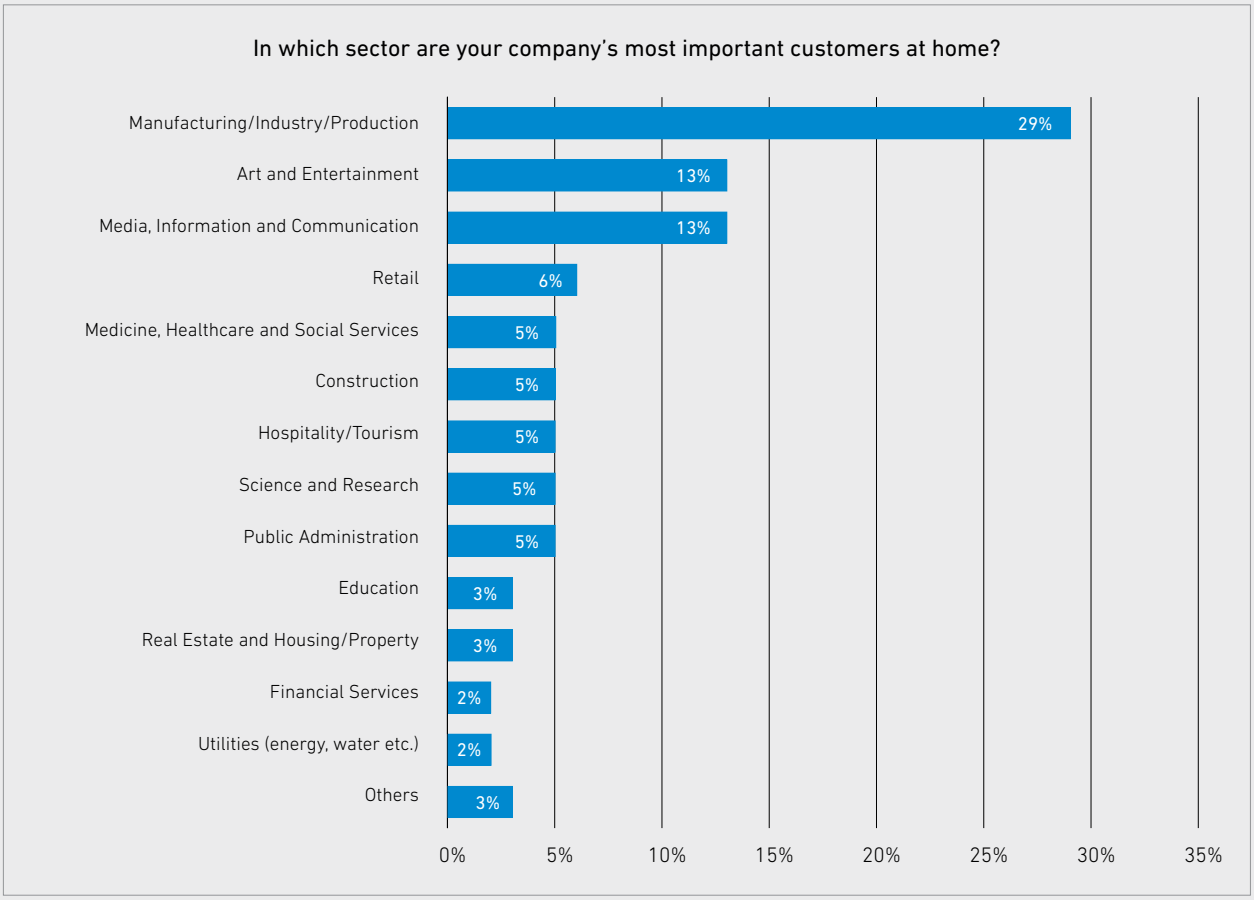


Source: Own data obtained by means of the representative online survey (n=130)

The survey asked about the most important target sector for each XR company to acquire a better understanding of the relative significance of each one *(cf. Figure 14).* Manufacturing, industry & production top the list by a clear margin here (29%/-1% compared to 2021). This is not surprising, as the automotive industry, for example – which has relied on these applications for some time – falls into this category. Many of the more lucrative applications are seemingly (also) made for this sector. It follows, therefore, that an analysis of companies with XR revenue of more than €500,000 reveals that 69% of these companies serve customers from at least one of the manufacturing industries. A similar picture emerges for the group of XR companies with more than five XR employees. 80% stated that they serve customers from manufacturing. Broadly speaking, the spread of customer segments gets wider with the size of the XR enterprises: While only three of the XR companies with revenue of more than €500,000 specialize in just one sector – the automotive industry – a good third (37%) have customers from more than 7 sectors.

There have been only slight changes in the ranking of most important customer sectors compared to the previous year's survey: Manufacturing was 1 percent higher in 2021 and represented the most important customer sector for 30 percent of respondents *(cf. Figure 17).* Like this year as well, it was followed in second place by the arts and entertainment sector with 13 percent (14% in 2021). Media, information and communication again comes third with 13 percent, as in the previous year, which corresponds to an increase of four percentage points.

Figure 17: Most important customer sectors for the XR companies



Source: Own data obtained by means of the representative online survey (n=129, no data: n=1)

Analysis from a regional perspective reveals a high dispersion of the 'most important sectors' nationwide, which suggests further differentiation of the market. No clear 'thematic' clusters of XR enterprises can be identified.

4. BUSINESS CLIMATE INDEX

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

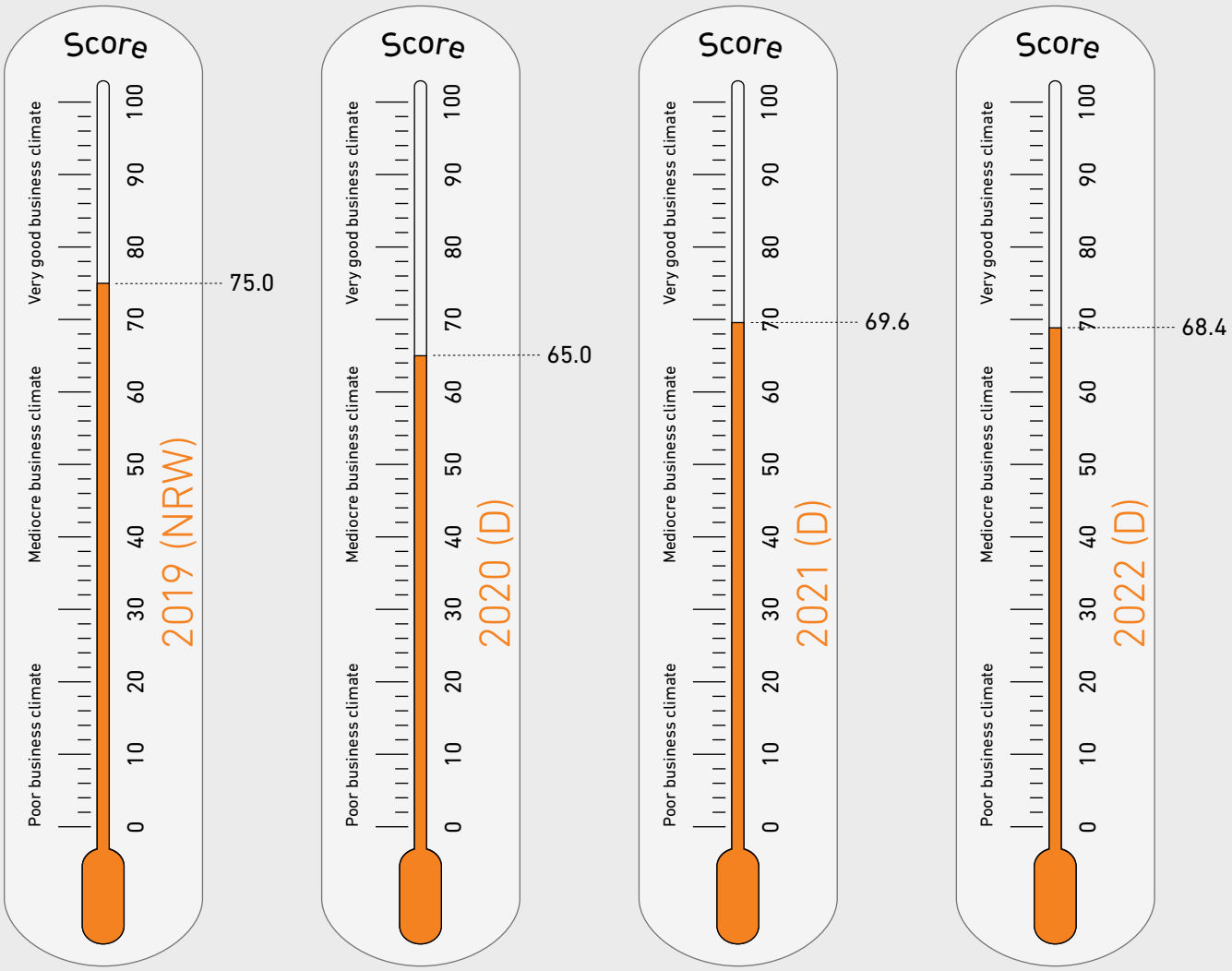
Aside from analysis of the current structure, the current business situation in the sector and the perceptions of XR companies in regard to future developments are naturally of particular interest as well. These aspects are identified using the Business Climate Index, which was developed specifically for the XR sector. Data is now available for four years, namely from 2019 (then only for NRW) to 2022. Developments of the sectoral economy can be tracked on the basis of this time series, as well as the effects of the COVID-19 pandemic.

The Business Climate Index inquires after the current situation, a retrospective year-on-year comparison and an outlook for the 12 months ahead. In line with the methodology used in the previous years' surveys, eleven dimensions are combined to form an overall score. This methodology permits a multi-factor assessment of trends and expectations among XR companies in Germany. Finally, calculation of the Business Climate Index enables a closer look at how the mood in the XR industry has evolved in Germany compared to the previous year.

Data collected on a 3-point and 5-point Likert scale was recoded to nine scale values in order to calculate the Business Climate Index (BCI) for the XR sector. Here, the scale value '1' represents the negative pole, e.g. 'bad' or 'decreased'; '5' denotes the average scale value for satisfactory/steady and '9' marks the positive pole, which stands for 'good', 'increased' or 'improving'. The individual factors influencing the Business Climate Index are weighted equally in the calculation. Each factor can reach a maximum score of nine in the calculation, assuming it is consistently rated very highly. Given that there are eleven factors in total, the Business Climate Index can hence reach the maximum value of 99 points. The maximum index value is normalized to 100 for better legibility.

With an overall score of just under 68.4 points of the maximum possible 100 points, the XR companies included in this survey currently assess the business climate in the XR industry as slightly positive. There has therefore been a slight decline compared to the previous year *(cf. Figure 18).*

Figure 18: Business Climate Index in the XR sector 2019–2022



Source: Own data obtained by means of the representative online survey (n=125)

This trend may seem highly surprising as (presumably at least) the worst phase of the COVID-19 pandemic appears to be over for the sector. However, the Business Climate Index also captures the mood going forward, which is consistently viewed more critically. It is evident that the current economic and geopolitical risks are having a negative impact on the business climate, as is clear in the individual indicators (*cf. Table 6):*

Table 6: Dimensions of the Business Climate Index in a comparison of 2021 and 2022

	Score for 2022	Standard deviation	Score for 2021	Year-on-year change
Current mood	6.1	1.7	6.3	-0.2
Mood for the coming 12 months	6.5	1.7	7.3	-0.8
Internal, significance of Germany as a location	5.0	1.9	5.1	-0.1
Current XR business situation	5.3	2.9	6.0	-0.7
Current order backlog	3.5	3.1	4.2	-0.7
Review of the demand situation	6.9	2.8	6.5	+0.4
Review of the order backlog	6.4	2.8	5.9	+0.5
Review of production activity	6.7	2.8	6.2	+0.5
Outlook on production activity	7.5	2.2	8.0	-0.5
Outlook on number of Employees	6.9	2.2	7.4	-0.5
Outlook: economic business situation	6.3	2.7	7.0	-0.7
Total Business Climate Index	**68.4**	**n/a**	**69.6**	**-1.2**

Source: Own data obtained by means of the representative online survey (2021: n=115; 2022: n=125)

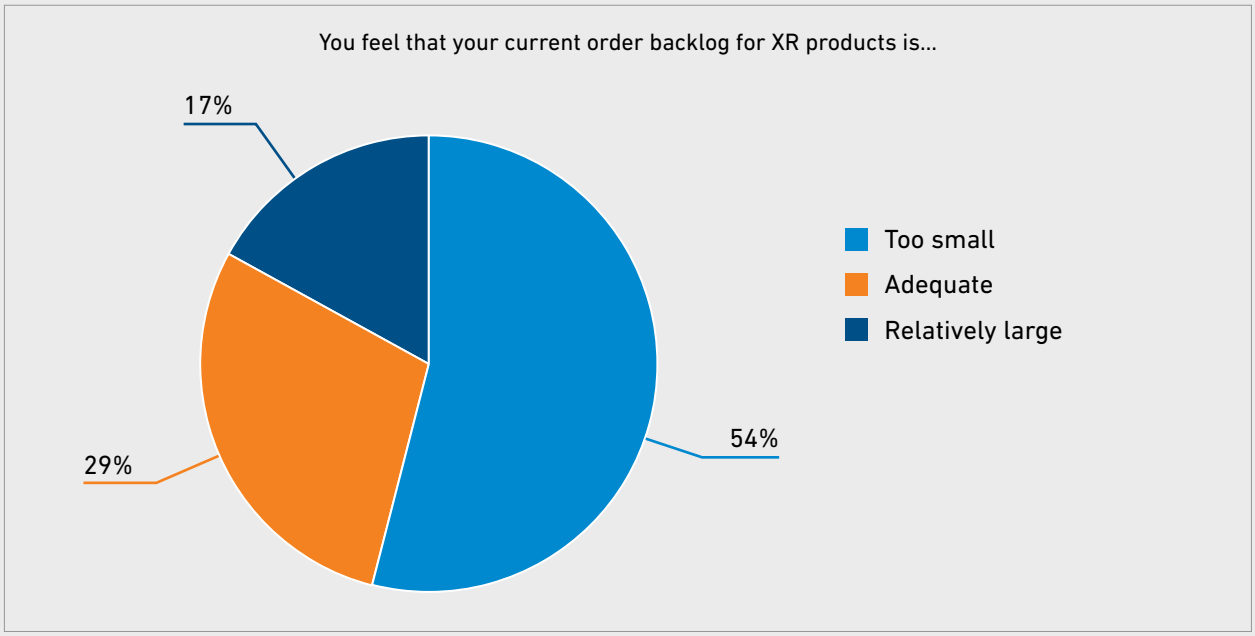
The high standard deviation of 1.7 to 3.1 shows that the companies or individual groups differ significantly in regard to their assessment. Micro-enterprises with up to five employees rate the business climate at only 64.4 points. Companies with more than ten employees see the situation far more positively, with an average of 71.9 points. Given that the greatest variances occur in the items that relate to the companies themselves, it is reasonable to deduce that the smallest companies see more difficulties in their business activities than larger companies.

The perception of the business climate also varies, depending on the area of XR on which the surveyed enterprises focus. Therefore, the 'high XR' enterprises (which focus at least 75% of activities on XR) rate the business climate with an overall score of 72.4 points, which is significantly better than companies for which XR only accounts for a minor part of their activities (<25%) or which only offer XR sporadically (61.7 points). The extent of XR activities (and likely the available specialized resources) impact differently on how the business climate is assessed as well. Enterprises with revenue of more than €500,000 and €1 million, respectively, rate their business situation at 76.1 and 76.4 points. By contrast, companies

with XR revenue of less than €100,000 assign a score of 60.5. There are large differences in the company-related criteria especially. The 'high XR' enterprises and the companies with significant XR revenue both rate these aspects on average one point more positively than companies that show little XR activity. This is indicative of specialization advantages playing an increasingly significant role in competition: Providers who offer XR only on the side or to a limited extent are at a disadvantage compared to their more focused competitors. By contrast, large and focused companies are in a better position to profit from opportunities in the XR sector and therefore have a more positive assessment of their possibilities and prospects.

The following takes a closer look at the individual dimensions to acquire a better understanding of the overall score. First of all, respondents were asked to assess their current situation based on order backlog, momentary business situation and prevailing mood in the sector. The only factor that is viewed particularly critically, with an average score of 3.5 (on a 9-point scale), is the current order backlog. The value has continued its downward trajectory from last year, falling by another 0.7 points. 54 percent of XR companies rate their order book as too thin (54%/+14% compared to 2021) or believe their current orders are just about adequate (29%/-14%). A mere 17 percent of the companies believe that their order backlog is comparatively large *(cf. Figure 19).*

Figure 19: Business Climate Index – Assessment of the current order backlog

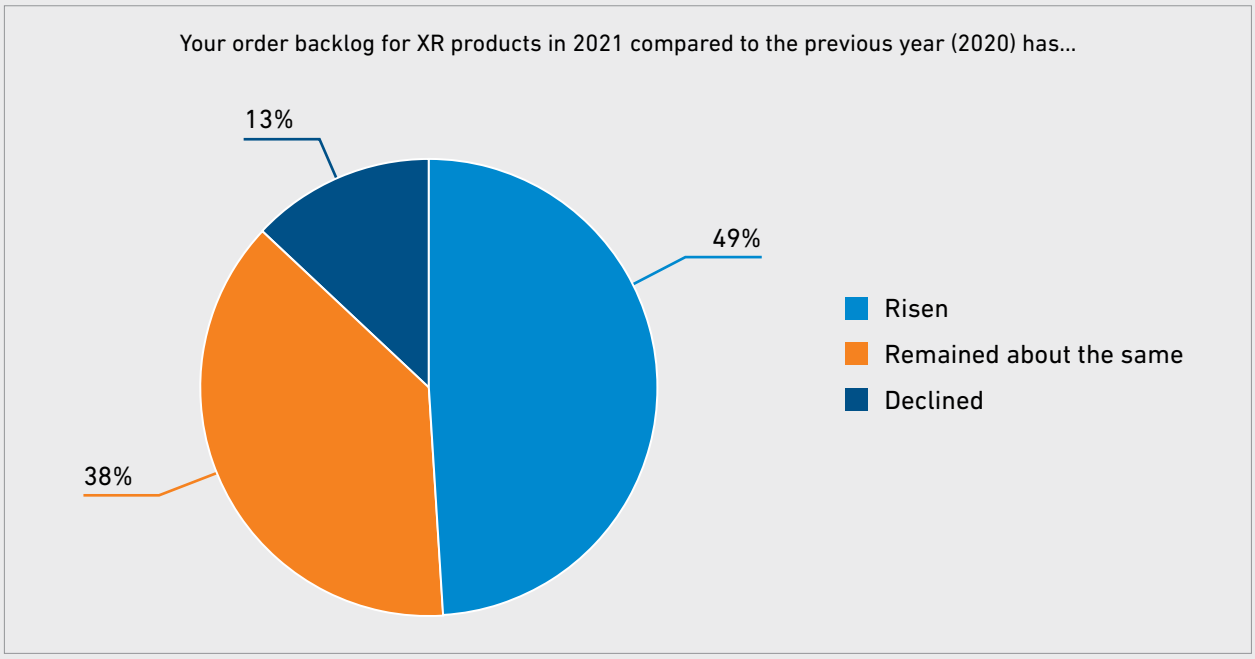


Source: Own data obtained by means of the representative online survey (n=130)

The momentary business situation (5.3/-0.7) is also rated worse than in the previous year; the current mood is roughly the same as in 2021 (5.2/-0.1). Therefore, the significant improvement in these indicators that we observed in the previous year (and which may also have contributed to the strong rise in revenue in the sector) has not continued and has even taken a downturn: Most companies have a more critical view of their current business situation.

This contrasts with the view of the past financial year, which is predominantly assessed as positive (and better than the current situation). Although the current order backlog is seen rather critically (see above), just under half of the respondents (49%) still report an improvement compared to the previous year. Only every eighth company states that last year's order backlog declined in comparison to 2020.

Figure 20: Business Climate Index – assessment of the current order backlog development 2021 vs. 2020

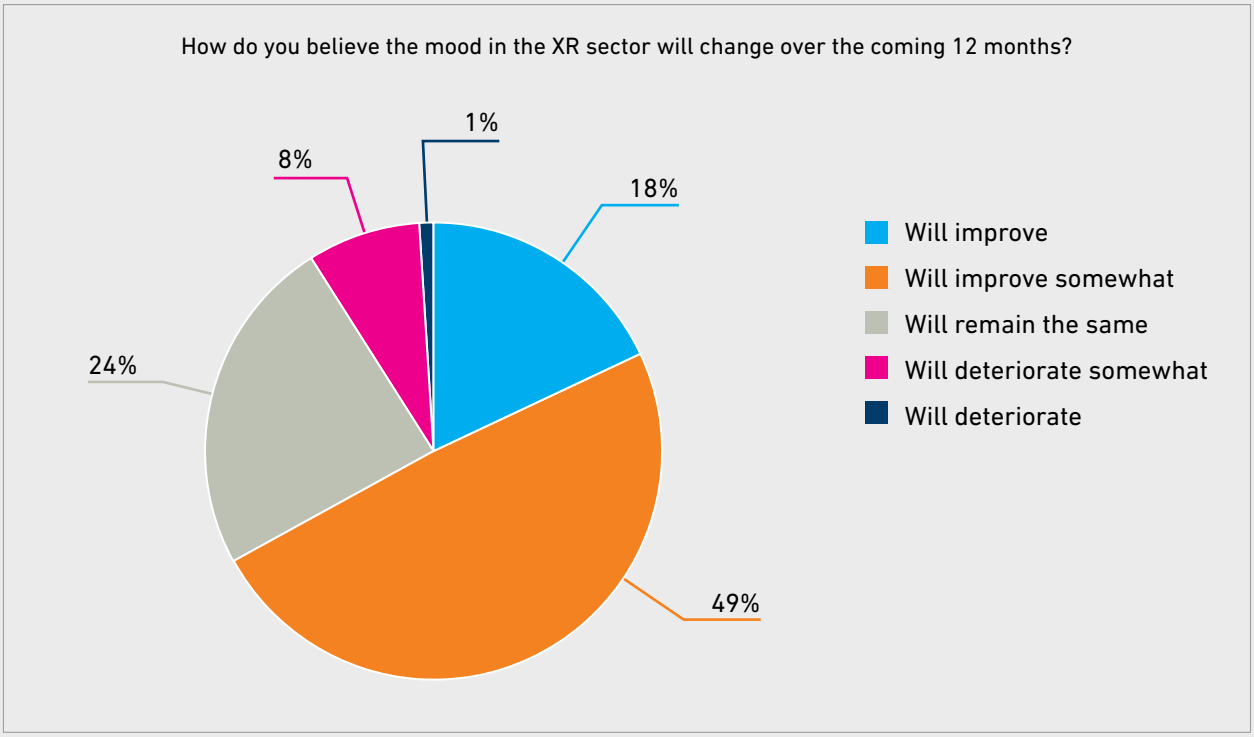


Source: Own data obtained by means of the representative online survey (n=129)

The third component of the Business Climate Index involves an assessment of future developments over the 12 months ahead. This comprises the individual dimensions of production activity, number of employees, economic business situation, future international importance of Germany as an XR location and how the mood in the XR sector is expected to develop going

forward. Two in three companies (67%) expect the mood in the XR sector to improve in the next 12 months – down from 85% in 2021. For the first time, 9 percent of the enterprises now believe that the mood is deteriorating (previous year: 1%). This demonstrates that the current economic and political risks are likely viewed as serious and long-lasting *(cf. Figure 21).*

Figure 21: Business Climate Index – assessment of how the mood in the sector will develop over the next 12 months



Source: Own data obtained by means of the representative online survey (n=129)

5. PROSPECTS: DEVELOPMENT OF THE VR/MR/AR MARKETS

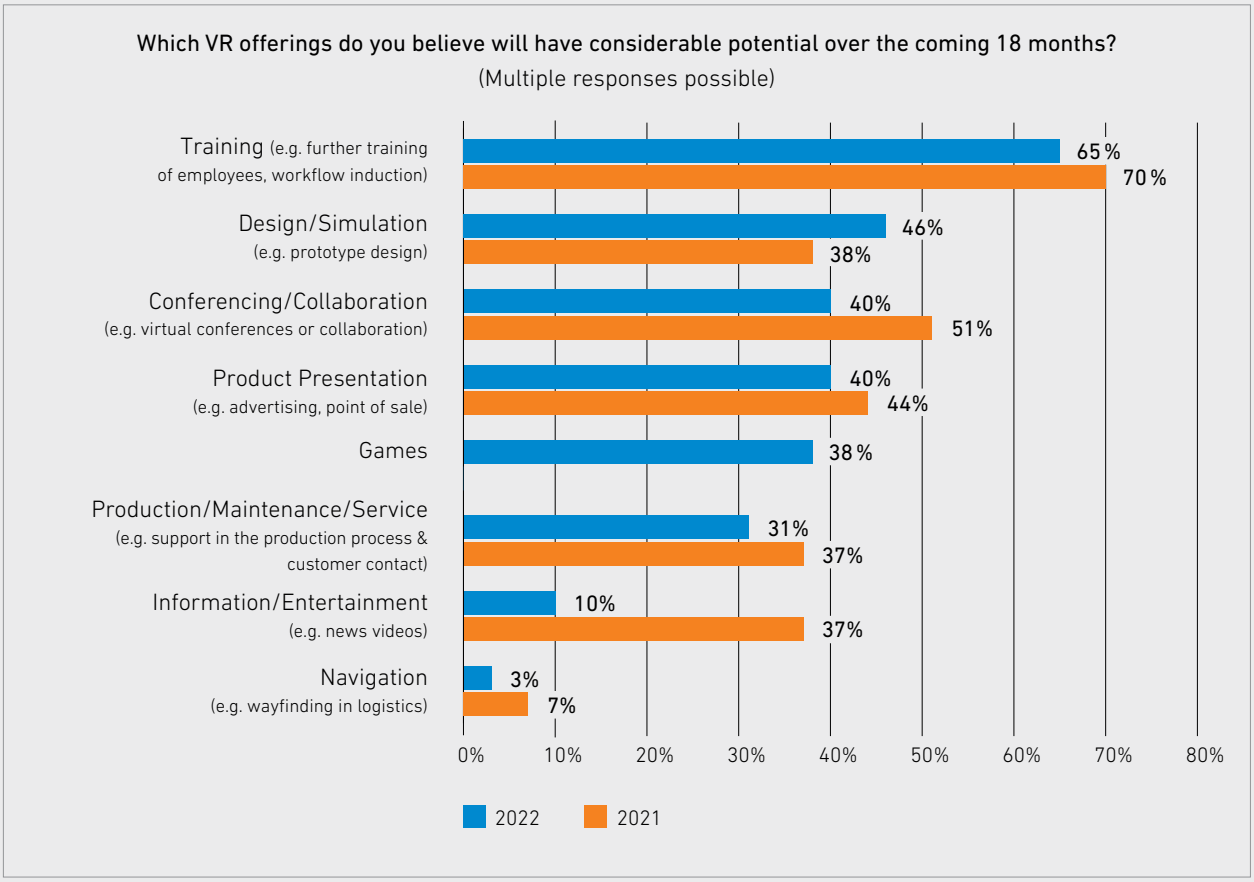
Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

The XR industry is exposed to highly dynamic developments – both from a technological and market perspective. The XR companies' forecast development for the 18 months ahead can provide information on which potentials are considered realistic in the near future, at least from the sector's perspective – and which obstacles the market is facing. Due to the plethora of meanings encompassed within the umbrella term of XR, these perspectives were surveyed separately in three basic fields of application: virtual, augmented and mixed reality. Participants in the survey were invited to provide their estimations on developments over the next 18 months in one of the three segments in which they consider themselves particularly specialized. This was done to ensure that the assessments deliver valuable insight. The majority of respondents saw their greatest individual expertise in the VR segment (n=68), followed by the augmented reality segment (n=42) and the mixed reality market, in which 20 respondents also claimed to possess the greatest expertise. The results were compared with the findings from last year's survey in order to identify any shifts.

5.1. VR

Respondents continue to hold that offerings in the VR segment of virtual training (65%/-5% compared to 2021) will remain the most attractive in the 18 months ahead. Design/simulation applications, on the other hand, are considered more attractive than last year (46%/+8%) and now rank second. By contrast, the experts believe that the significance of solutions for conferencing/collaboration has waned considerably (40%/-11%), although they still come third. This may be due to the recent sharp increase in work at the office, which has reduced the need for these solutions. New to the list is segment of games, which features as a separate category for the first time and comes in at 38 percent. Respondents also express a more reserved assessment as to the potential of applications in production/maintenance/service (31%/-6%). But the trend in the segment of informative or entertaining (content) offerings is particularly striking (10%/-27%). Only 10 percent believe that this segment has high potential. The assessment has therefore experienced a strong negative change over time: 65 percent of the respondents in the survey we conducted in late 2017 as part of our first study (at that time only for NRW) still considered this segment to be highly attractive. This points to the long-term problems of device distribution and refinancing models in the B2C market. Finally, the respondents do not expect the segment of wayfinding/navigation to hold any noteworthy relevance for the future of VR (3%/-4%).

Figure 22: Potential of VR offerings (next 18 months)



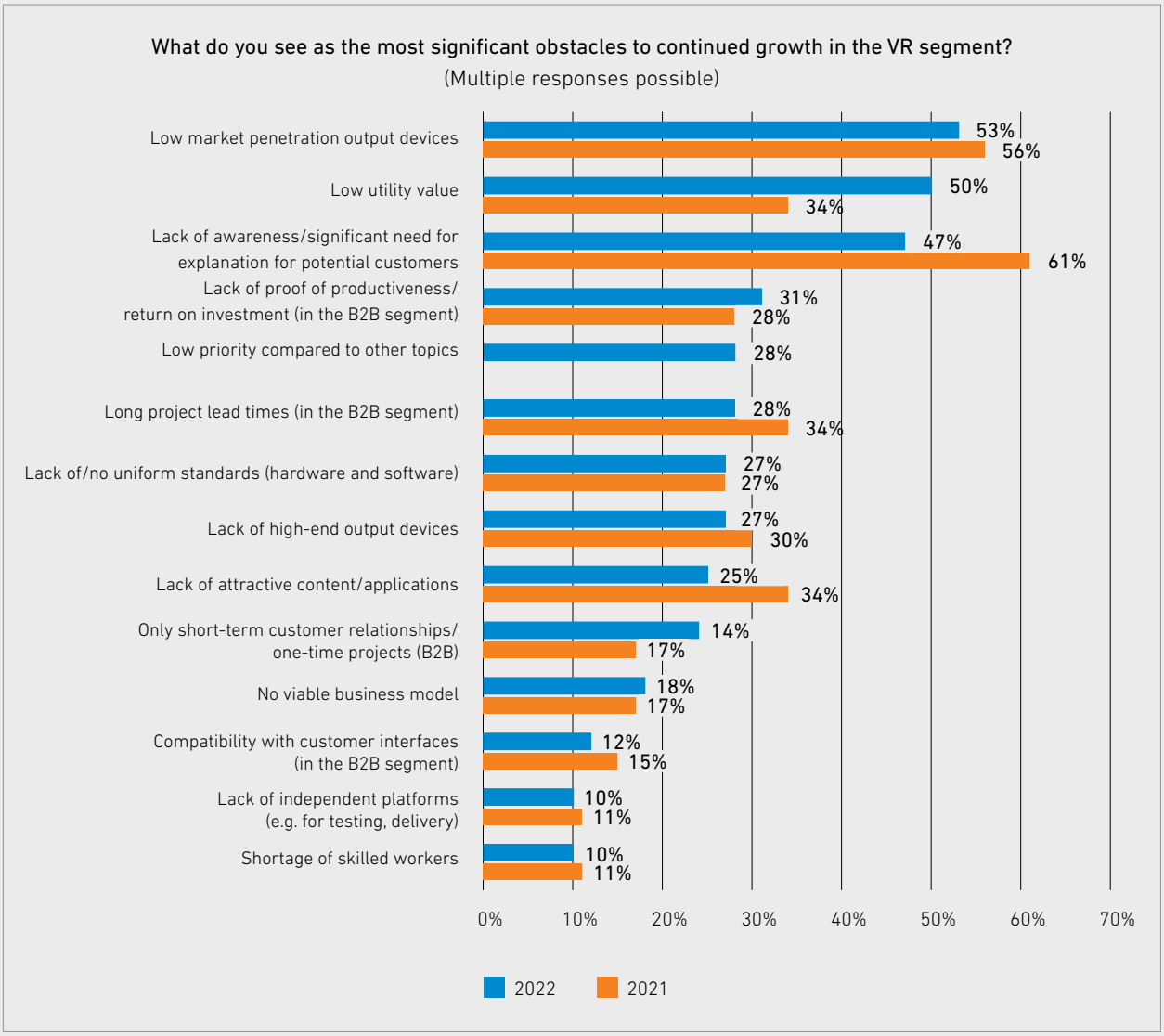
Source: Own data obtained by means of the online survey (n=68)

Virtual reality has still not been able to establish a firm footing on the German market, at least not at a level even roughly comparable to the smartphone segment. We therefore asked the XR producers to state the greatest obstacles impeding the growth of the VR segment *(cf. Figure 23)*. In this case the majority of respondents cited two aspects they believe to be central: The continued low distribution of devices (53%/-3% compared to 2021) one the one hand and the low utility value (50%/+16%) on the other are perceived as the greatest obstacles. By contrast, lack of awareness is mentioned far less frequently as a significant obstacle (although still 47%/-14%). These aspects indicate that the actual usability or sustained utility value is increasingly perceived as an obstacle in the consumer market. This is matched by the fact that a lack of attractive content is now viewed as an obstacle far less frequently (25%/-9%), which suggests that the offering seems to be improving. Challenges associated with the absence of proven productive use comes next by a significant margin (31%/+3%). Low priority compared to other topics was included as a new item and was viewed as a significant

obstacle by just over every fourth respondent (28%). The long lead times is a highly relevant aspect for the B2B segment, but was cited less frequently as an obstacle (28%/-6%). But the lack of standards (and interoperability, 27%/+0%) and high-end devices (27%/-3%) remains more or less unchanged. There are clear shifts compared to 2017: Lack of customer awareness (at that time the most important hurdle at 67%) has declined in importance. The lack of high-end device penetration has become somewhat less important, but remains the second most significant obstacle, as it was five years ago (2017 value: 58%).

Figure 23: Most significant obstacles to growth in the VR segment

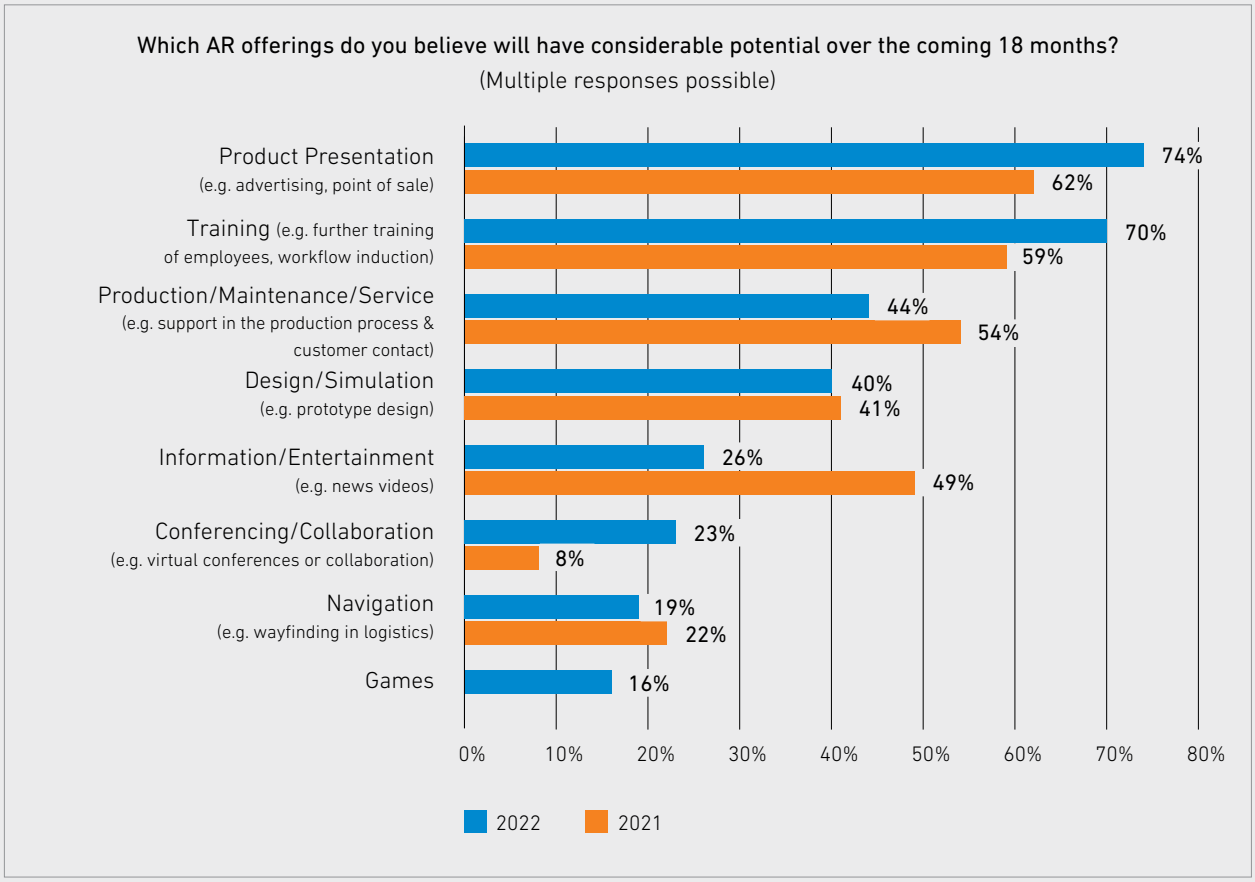
Source: Own data obtained by means of the online survey (n=68)



5.2. AR

Augmented reality already represents a relevant category of offering for most of the companies surveyed *(cf. Chapter 3.2.).* But there have been significant changes in expectations as to which application categories are promising in this segment. The majority of expects now anticipate that the product presentation and experiences segment will show the biggest potential over the next 18 months (74%/+12% compared to 2021). The fact that AR applications are relatively easy for most users to run on their smartphones might be relevant here. Accordingly, public spaces, trade show booths and similar venues are suitable places for relevant use cases. Like in the VR segment, the respondents believe that the area of training is highly relevant, even more than it was 12 months ago (70%/+11%). The lower entry thresholds may also present a significant opportunity in this case. Individual B2B use cases in the area of production, maintenance and service have declined significantly (44%/-10%). The prospects for design and simulation applications (40%) remain unchanged. Like in the VR segment, entertainment/content-based applications are viewed as less relevant. Only 26 percent believe that information and entertainment possess significant potential. This is 23 percentage points below last year's result. At the same time, however, games are also considered a rather lower-potential category with 16 percent. This is remarkable if one considers that Pokémon Go is cited as a prime example of AR applications for smartphones. The respondents are surprisingly cautious in regard to the segment of AR-based navigation (19%/-3%), which is also a classic use case for AR. Expectations have risen in the segment of conferencing and collaboration, fueled perhaps by numerous video chat/online conferencing providers (e.g. Zoom, Microsoft), which often run on smartphones. There has been a noticeable shift in priorities compared to our first survey in 2017 (in which we inquired as to the combined attractiveness of AR and MR): Experiences and product presentations, which were named fourth (53%) in the list of most promising applications at the time, rank right at the top in 2021. But training was already perceived to have a promising future in 2017 (68%), followed at the time by production/maintenance/service (65%) and design/simulation (56%) applications.

Figure 24: Potential of AR offerings (next 18 months)



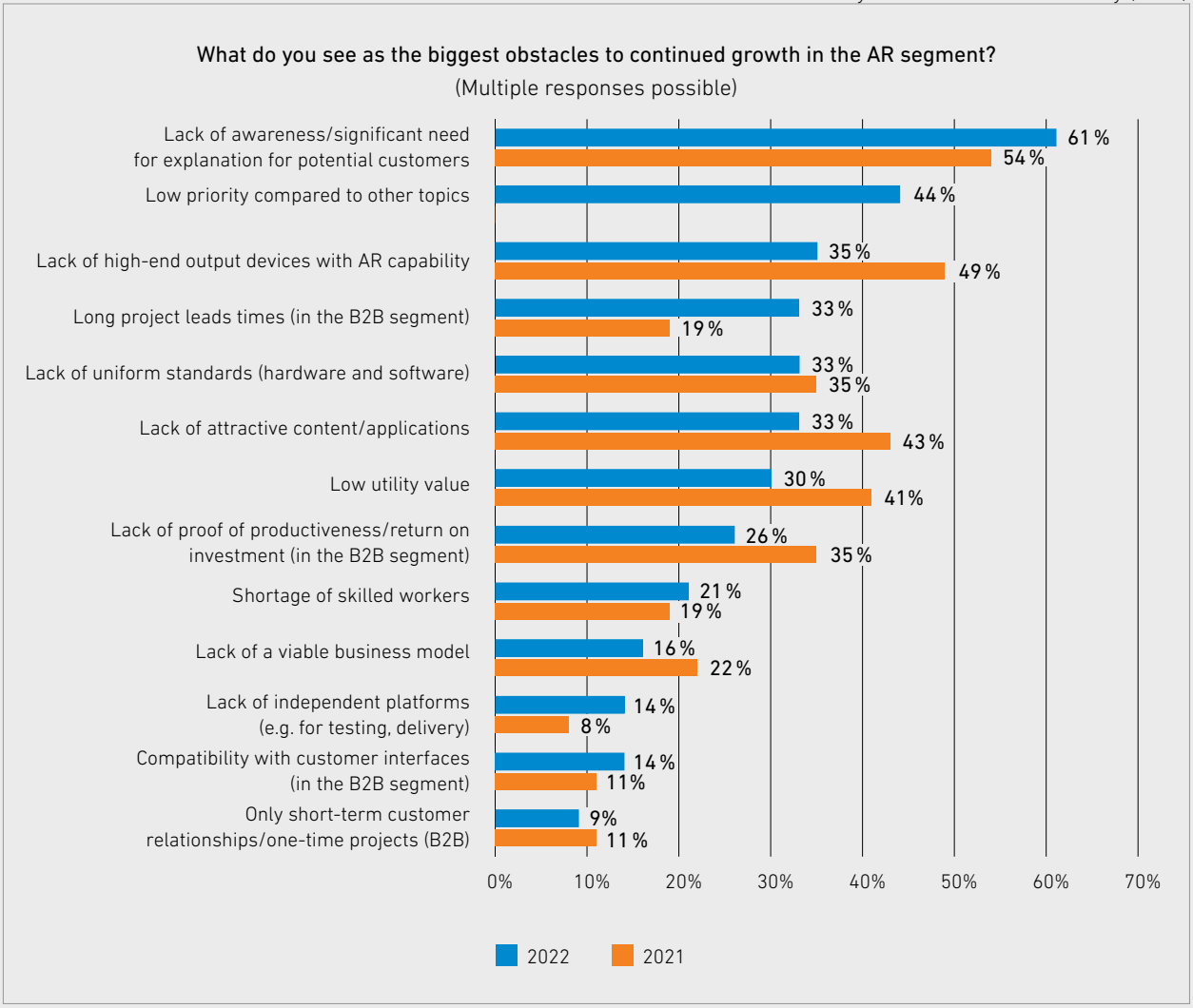
Source: Own data obtained by means of the online survey (n=42)

An evaluation of the most significant obstacles for AR shows that many are viewed as less relevant by the respondents than was still the case in 2021 *(cf. Figure 25)*. But there has been an increase in the share of respondents who perceive the lack of awareness and the need for explanation as the most significant obstacle (61%/+7%). In second place comes the 'new' item of low priority compared to other topics (44%). There is also a lack of high-end devices, although the situation appears to have improved significantly year-on-year (35%/-14%). With regard to the increasing commercialization in the B2B segment, one in three (and therefore considerably more than in the previous year) believes that the long lead times for these projects represent a significant obstacle (33%/+14%). This is just as many as those who perceive the lack of uniform standards as a major problem (-2% compared to 2021). By contrast, some of the other, lower-ranking obstacles are mentioned far less frequently, among them the low utility value (30%/-11%) or the lack of proof for ROI (26%/-9%). This might suggest that – given the lower entry thresholds – demand is actually stronger and

more vigorous than in the VR segment. The shortage of skilled workers is viewed as a far more significant obstacle to growth than in the VR segment (21% vs. 10% in the VR segment). Output device performance has evidently improved considerably compared to our first survey in 2017: At that time, 69 percent of respondents saw performance-related factors, among them displays, as the biggest obstacle, followed by a lack of content and applications (64%).

Figure 25: Most significant obstacles to growth in the AR segment

Source: Own data obtained by means of the online survey (n=42)

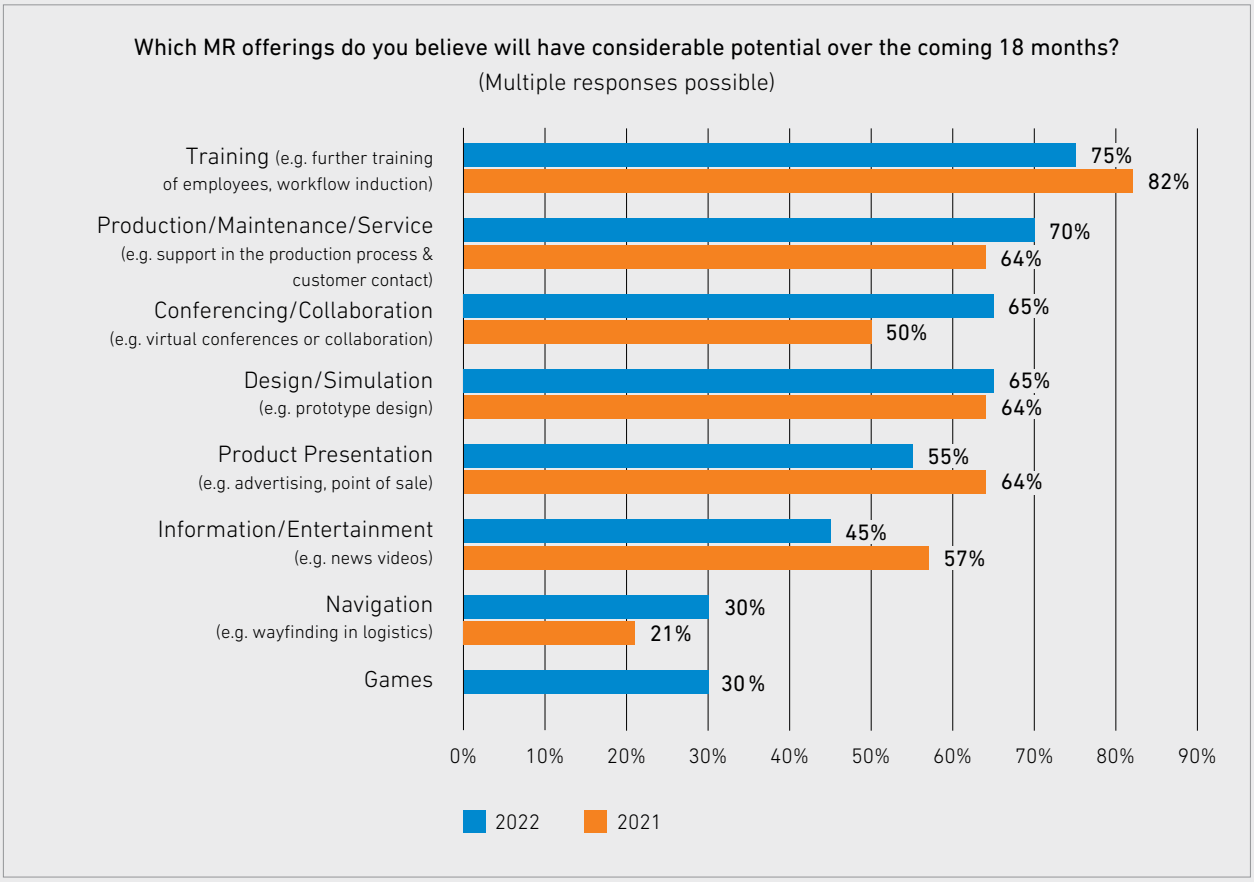


5.3. MR

Mixed reality applications have attracted greater attention more recently than in previous years due to the advent of more powerful devices. Thanks to the 'hands free features', various

studies already predicted or outlined application scenarios in industrial settings for this form of XR relatively early on. Like last year, the category of training shows by far the greatest potential for MR (75%/-7% compared to 2021). By contrast, the expectations for applications in production/maintenance/service have risen slightly (70%/+6%). The more positive assessment for conferencing/collaboration is even more pronounced (65%/+15%). This positive forecast may also be related with future hardware generations – such as those announced by Marc Zuckerberg for his Meta Group. Going forward, they may significantly facilitate integration into 'normal' working routines. While design and simulation solutions remain almost unchanged as attractive application categories for almost two-thirds of respondents (65%/+1%), 55% (-9%) still see have the same view of experiences and product presentations. Information and entertainment applications are also seen more critically in the MR segment, albeit to a lesser extent than in the other two (45%/-12%). This may also relate to the fact that corresponding applications are still relatively uncommon or rather conceptually abstract. Finally, 30 percent believe that both navigation applications (+9% compared to 2021) and games possess significant potential. The assessments are thus largely consistent with the expectations regarding the potential of AR and MR from 2017 that have already been briefly outlined. Even then, training was rated as the most promising application (68%), followed by production, maintenance and service (65%) and design/simulation (56%). Only navigation systems were considered significantly more attractive at the time (2017 value: 53%).

Figure 26: Potential of MR offerings (next 18 months)

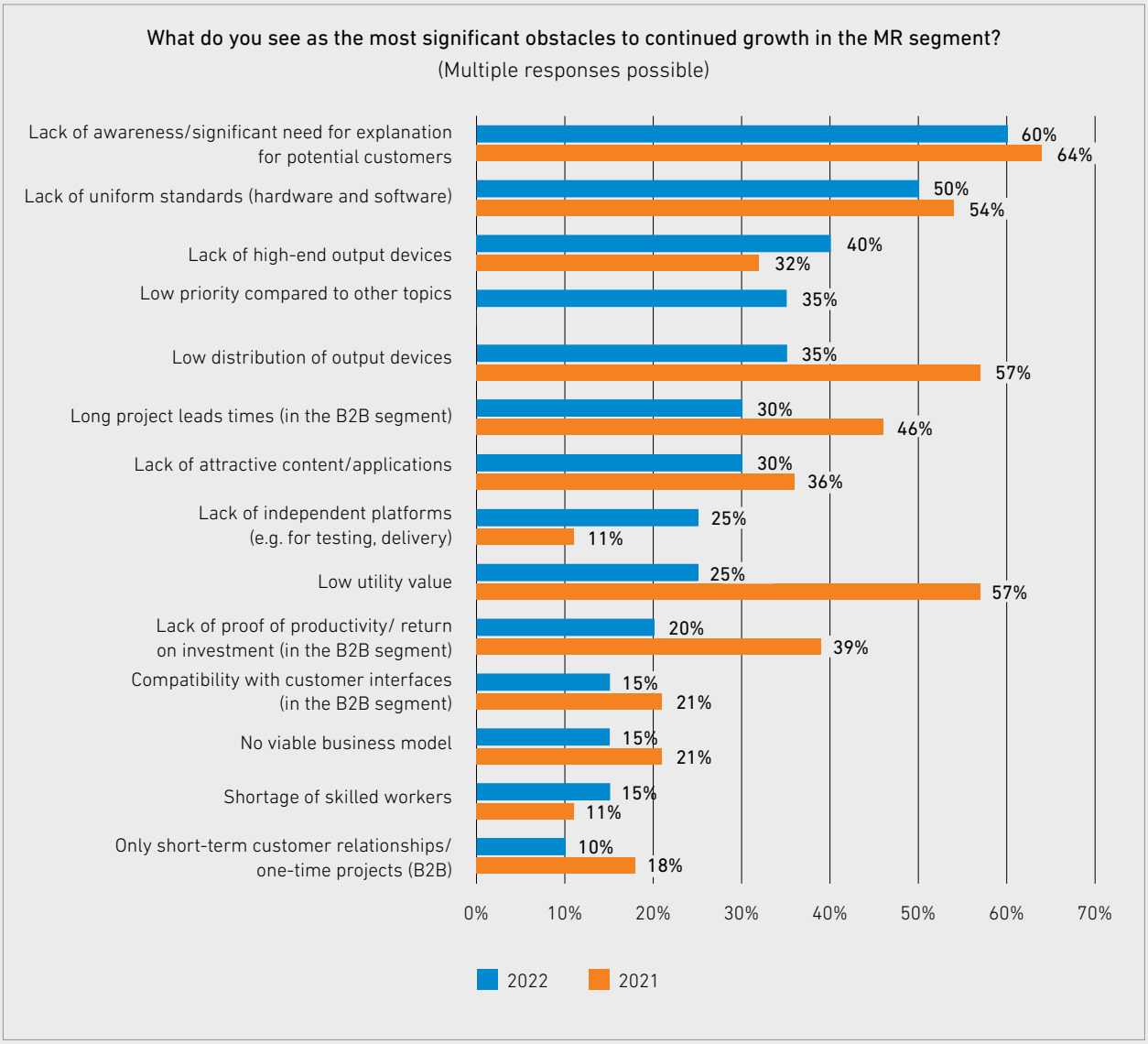


Source: Own data obtained by means of the online survey (n=20)

There have been stark changes compared to last year in the assessment of the most significant obstacles in the MR segment *(cf. Figure 27)*. This most likely reflects the momentum in the development of MR headsets. Thus, although the lack of awareness/distribution remains the most significant obstacle (60%/-4% compared to 2021), low distribution (35%/-22%) and low utility value (25%/-32%) have become far less significant as obstacles compared to 2021. The lack of standards are now rated second as perceived obstacles (50%/+4%). Device quality is also viewed somewhat more critically compared to last year (40%/+8%). On the other hand, business-side barriers – including long project lead times (30%/-16%) or lack of proof for productivity (20%/-19%) – have improved a little in the rating. Aside from the low priority compared to other topics (35%), the lack of independent platforms is also viewed as a critical factor (25%/+14%). This issue – how to deal with large platform companies – was also a priority of this year's survey *(cf. Chapter 6)*. It follows, therefore, that there are quite considerable differences compared to the first survey of the MR segment in 2017. At

that time, performance and content-related aspects topped the list of obstacles (high-end devices: 69%; lack of content: 64%); customer awareness 'only' came third at 58 percent.

Figure 27: Most significant obstacles to growth in the MR segment



Source: Own data obtained by means of the online survey (n=20)

6. DIGITAL ECOSYSTEMS & THE METAVERSE

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

Among the benefits of this long-running study series is the ability to investigate different topics in depth, and not just to compare them over the passage of time. While the 2021 study focused on the network relationships between XR companies (and 2020 on the role of locations and clusters), this one examines the role of digital ecosystems in the XR industry in more detail (Chapter 6.1.). One particular aspect that is the subject of considerable debate is the metaverse, so the XR companies were also requested to answer questions in this regard (6.2.).

6.1. Digital Business Ecosystems (DBE)

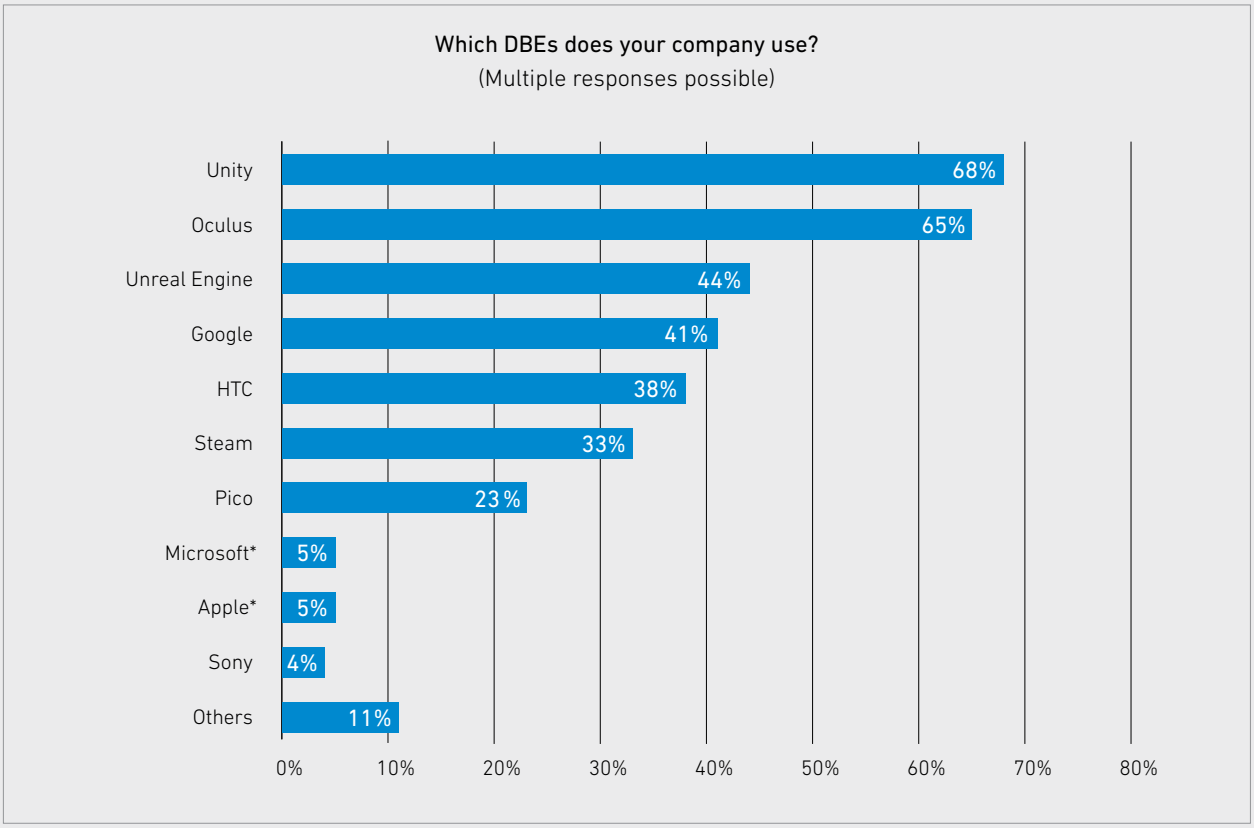
Digital ecosystems are playing an increasingly major role in Germany. This is no different in the XR sector, as evidenced by this year's survey. Digital Business Ecosystem (DBE) is the term that is used in academic literature. A DBE can be described as "an extension of Moore's business ecosystem in which digital technology plays a dominant role" (translated from Senyo et al., 2019, p. 53). DBEs are collaborative networks of heterogeneous and geographically dispersed companies and organizations. These maintain a variety of relationships with each other that extend beyond generic service relationships (such as purchasing from a supplier), in which the companies may, for instance, develop new products together. The crucial aspect is that these relationships are not completely controlled by a defined hierarchy. Symbiosis, co-evolution and self-organization are therefore the hallmarks of DBEs *(Jacobides et al., 2018).*

Moreover, DBEs build on a common digital system, often a technological platform which is most commonly operated by a software/hardware vendor. These 'focal actors' play a central role in shaping the DBE, as their strategies for orchestrating the ecosystem may influence and limit the market behavior, innovative capability and competitiveness of other, non-focal enterprises *(Hein et al., 2020).* The DBE therefore provides the framework for all enterprises that are active on the same common platform. They can collaborate or even compete there. One example: All XR enterprises using Oculus VR headsets are part of the Oculus DBE. An XE company can participate in several DBEs at the same time.

As a first step, XR enterprises were invited to state in which XR-related digital ecosystems they operate. It becomes apparent that the Oculus DBE is, by a considerable margin, the most frequently cited hardware-based DBE. The choice of virtualization software is of particular significance on the software side: Here, two thirds of the enterprises pick Unity, the market

leader, while 44 percent stated that they use Unreal Engine. The overlap of just 41 enterprises was relatively low in this case (31%). The free response category 'Others' was also chosen more often, at 11 percent. Examples of responses include Samsung and Magic Leap.

Figure 28: Digital ecosystems in the XR sector

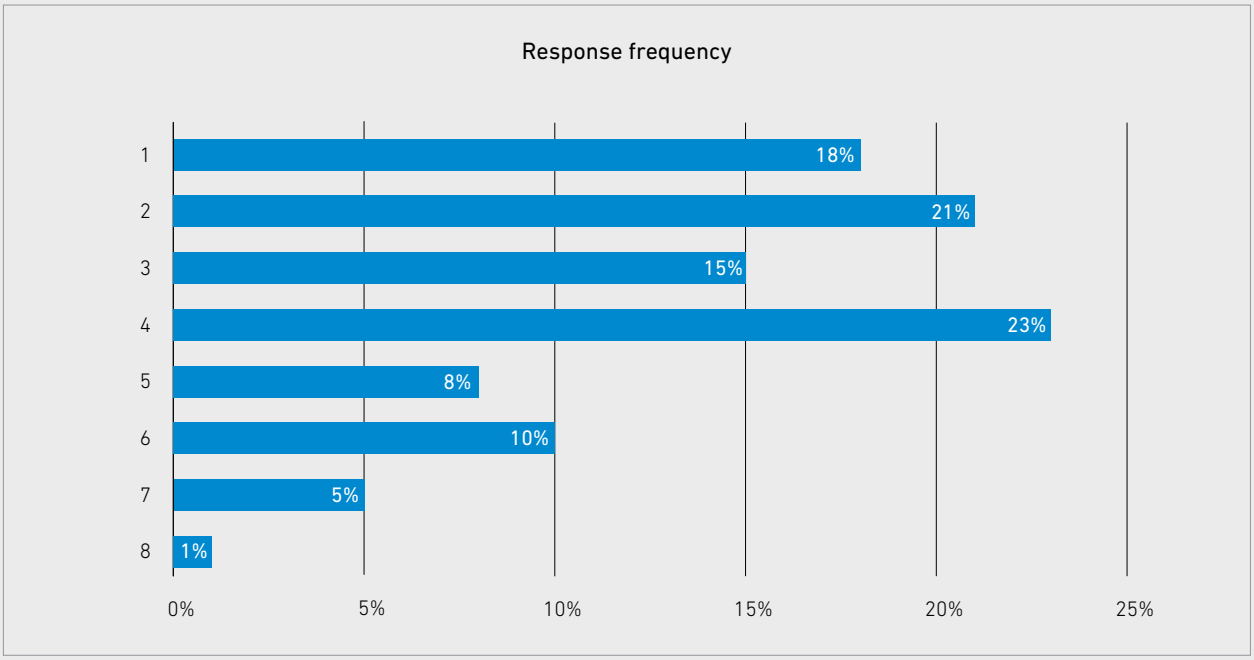


Source: Own data obtained by means of the representative online survey (n=130).
** = cumulated from free-field entries under Others.*

There is significant variance in regard to the differentiation. 'High XR' enterprises use Unity far less frequently than their 'low XR' counterparts (61% vs. 73%). The same applies to Unreal (31% vs. 48%); the reason for this may be that this group focuses more on other or proprietary virtualization frameworks. Low XR enterprises are more likely to use Google as an ecosystem (41% vs. 29%), whereas 'high XR' enterprises use PICO (37%) significantly more frequently than those with a low XR focus (14%). Oculus is, however, the most important hardware DBE in both groups (69% and 61%).

Just under 18 percent stated that they are active in only one DBE. But the majority (53%) use up to three different DBEs. Just under a quarter of the companies included in the representative survey are involved in four DBEs; 24 percent are even active in five or more DBEs *(cf. Figure 29).* Participation in DBEs also depends strongly on the amount of available resources: While enterprises with fewer than 5 XR employees participate in an average of 2.9 DBEs, those with more than 5 XR employees participate in almost one additional DBE on average (3.7).

Figure 29: Number of DBEs used by the XR companies

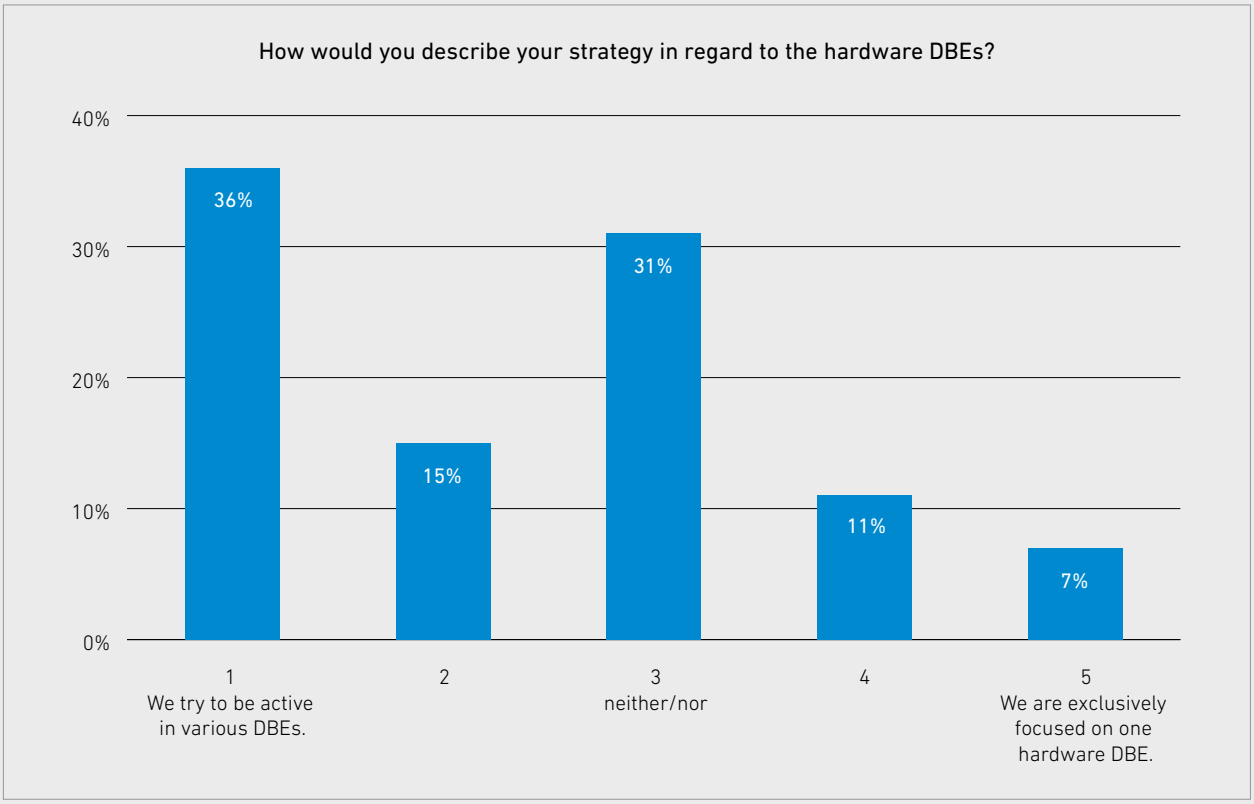


Source: Own data obtained by means of the representative online survey (n=130)

The varying efforts of the XR companies to define a focus are also reflected in their strategic alignment. Academic literature discusses this aspect using the terms single or multi-homing. The underlying question is whether it makes more sense for a company in a DBE to focus on one DBE (in order to then generate specialization advantages) or to align itself with different DBEs, which enhances their flexibility and reduces dependencies, but may significantly increase adjustment costs at the same time *(Chen et al., 2022).* The survey reveals that multi-homing is a relevant topic for most providers: Just over half (51%) of the XR enterprises state that they fully or predominately pursue a strategy of alignment with different DBEs.

By contrast, just under a fifth stated that they are predominantly or exclusively focused on just one DBE. A third do not possess a clear strategy in this respect. There are only minor differences here based on XR focus or company size.

Figure 30: Multi-/single-homing strategies among the XR companies

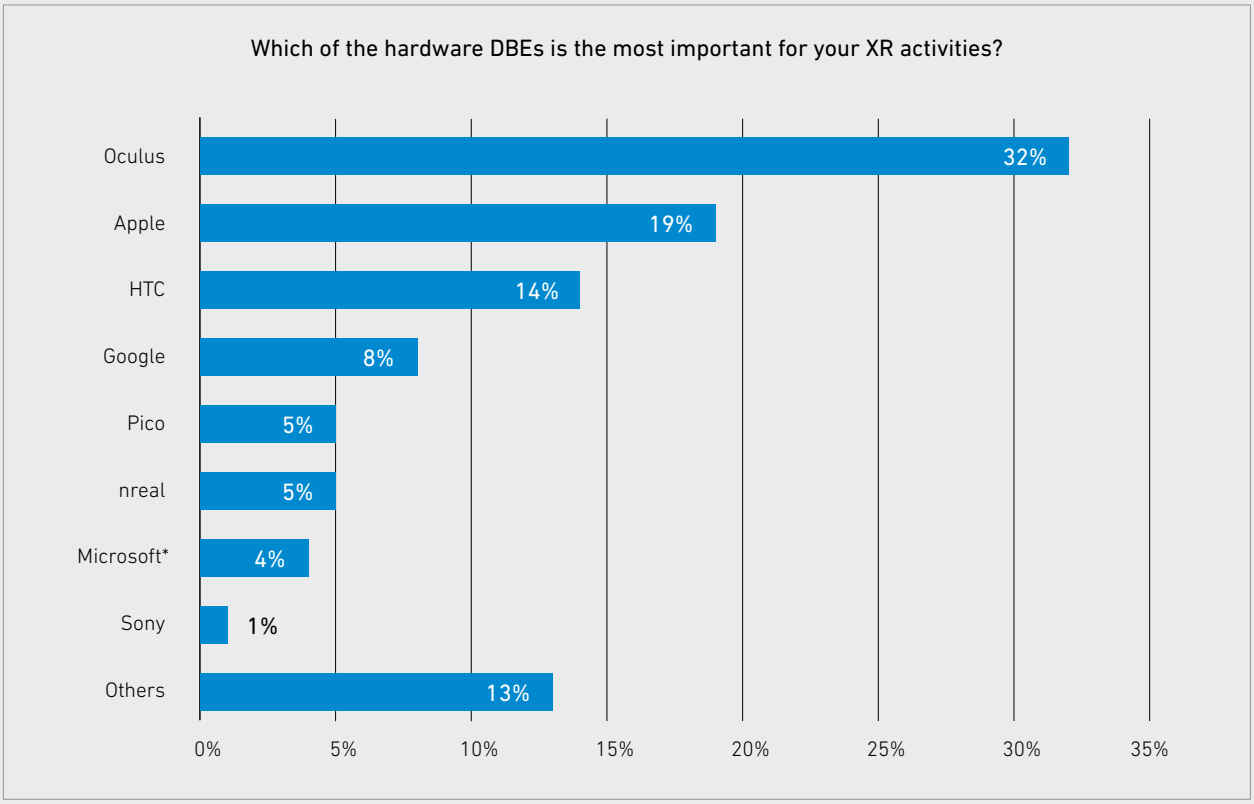


Source: Own data obtained by means of the representative online survey (n=130)

For further analysis, the enterprises were requested to indicate their most important hardware-based DBE. The strong position, i.e. considerable significance of the Oculus DBE, is apparent here as well. It tops the list by a clear margin (32%), followed by Apple (19%). This is very significant with a view to the AR market. 94 percent of the companies that cited Apple as the most relevant hardware DBE (at least also) offer smartphone-based AR. Interestingly, Google is mentioned far less frequently, although it has not only the numerically larger customer base with Android, but is also active in the VR sector. The strong overall position of Oculus is noteworthy, as Oculus has recently discontinued or largely scaled back its efforts and collaborations in the B2B sector – and this area is highly significant in the German XR industry *(cf. Chapter 3.5.)*.

HTC – which a respectable 14% view as the most relevant DBE – then trails by a considerable margin as a VR-based hardware ecosystem. Again, a high number of individual statements (13 percent) were submitted concerning the most important hardware DBE. They included single mentions of Samsung or Magic Leap.

Figure 31: Most important digital ecosystems in the XR sector



Source: Own data obtained by means of the representative online survey (n=130).
** = cumulated from free-field entries under Others.*

The XR enterprises were requested to provide further assessments – related in each case to the most important hardware DBE for the respective company – in order to gain deeper insight into the form of collaboration within the XR DBEs *(cf. Table 7).* Broadly speaking, contribution to the most important hardware DBE is considered to be very significant: On average, the companies rated this factor with a value of 4.9 on a 7-point scale (where 1 indicates 'do not agree at all' and 7 indicates 'agree fully'), affirming its ability to increase corporate performance. At 5.5, the value for companies that indicated Apple or Google as their most important hardware DBE is particularly high. While the companies were still relatively

cautious to assert that participation in the DBE would increase profitability (value of 4.65), they nevertheless placed a comparatively strong emphasis on the possibility to enable more innovative concepts (5.23). The pronounced standard deviation of 1.41 to 1.64 is striking here, which is indicative of strategic differentiation.

Moreover, their own role in the DBE is interpreted far more conservatively. In this respect, the enterprises tend to believe that they contribute less to the success of others: The statement "Other companies in the DBE would be unable to achieve their strategic goals without our help" was affirmed with an average value of just 3.14, also with a high standard deviation. This underlines the fact that most of the enterprises, as complementaries of the platforms, may rely on individual DBEs, but themselves only make a smaller contribution to the success of the overall system. At the same time, they assess the significance of the most important DBE for implementation of their own strategy much higher, with values of 4.22, i.e. 4.45.

Overall, collaboration with other actors who are not platform operators is viewed with more caution. The enterprises affirm the survey items with a value of 2.9 (on a 5-point scale), which corresponds to a neutral attitude. This takes into account collaboration with other enterprises to achieve a common goal, alternative forms of intense collaboration or the exchange of information with others in the DBE. But a significant strategic divergence does become apparent here: For example, the enterprises that have assigned a rating of 4 or 5 to at least one collaboration item achieve an average of approximately 4.0 for all items. This is true of almost exactly 50 percent of the sample – so exchange and joint value creation with other, non-focal actors is definitely highly relevant to these companies. It follows, therefore, that an almost equally sized group finds collaboration in the DBE rather irrelevant. This is also consistent with our findings from previous years, which have shown that networking activities and local and supra-regional exchange relationships are highly important to various groups of actors, but not to other groups in the same extent *(Zabel et al., 2021; Zabel & Telkmann, 2022).*

Table 7: Collaboration and competition in DBEs

Items	Mean value (7-point scale)	Standard deviation
Performance in the DBE: "Our collaboration in the DBE enables us to..."	**4.91**	**n/a**
... improve product designs or the organization of production processes.	4.91	1.41
... improve the marketing or sales of our products/services.	4.83	1.56
... make our services/products more profitable.	4.65	1.54
... develop more innovative strategies.	5.23	1.64
Importance of the central DBEs:	**3.94**	**n/a**
We would not be able to achieve our strategic goals without participating in the DBE.	4.22	1.88
Other companies in the DBE would be unable to achieve their strategic goals without our help.	3.14	1.73
Our company obtains many strategic benefits by participating in the DBE.	4.45	1.58
Items	**Mean value (5-point scale)**	**Standard deviation**
Significance of other actors who are active in the DBE: "In our organization..." (5-point scale)	**2.96**	**n/a**
... we collaborate with other companies that are active in the DBE to achieve a common goal.	2.97	1.33
... we often share relevant information with other companies that are active in the DBE.	2.98	1.32
... we collaborate strongly with other companies that are active in the DBE.	2.93	1.39

Source: Own data obtained by means of the representative online survey (n=130)

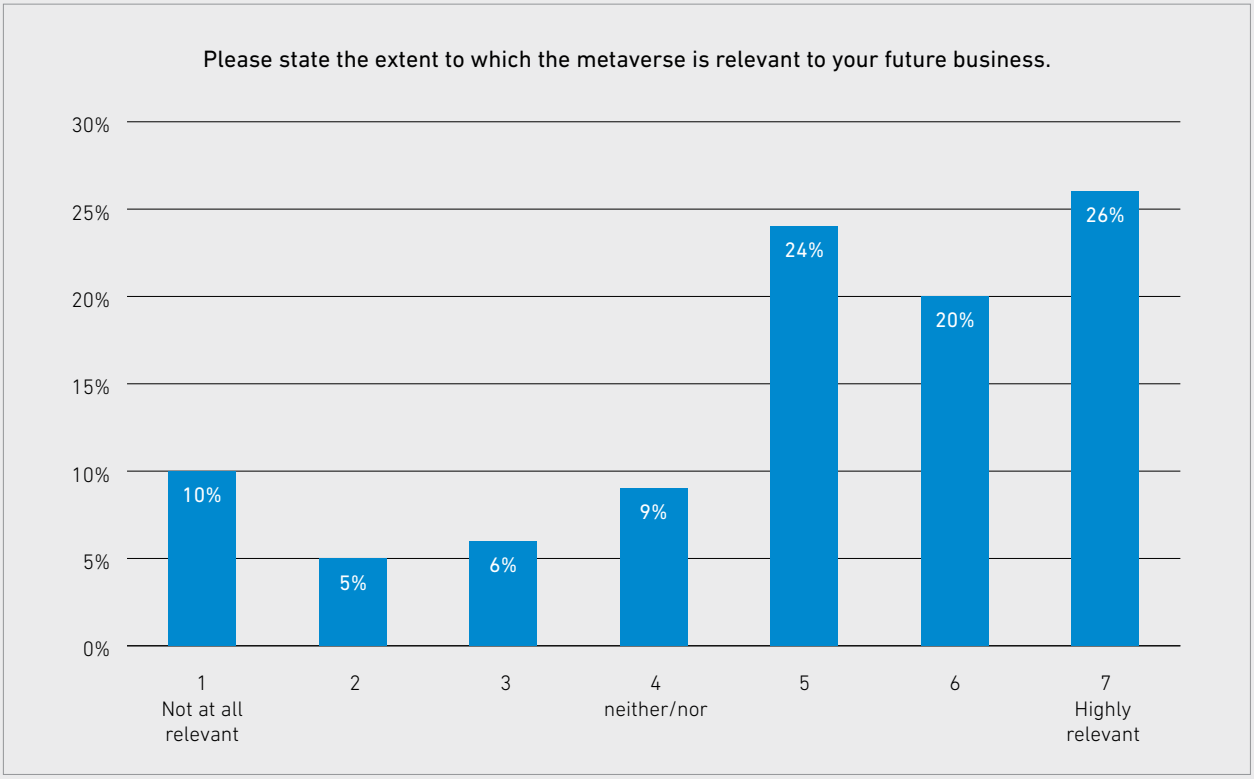
6.2. Metaverse

Numerous companies, among them Disney, have come forward with their own plans since Facebook CEO Mark Zuckerberg announced his intention to structure the entire company around this new virtual reality. Prior to that, platform games such as Fortnite or Roblox had achieved considerable success with an innovative blend of real and virtual worlds; some observers already view these games as a potential part of the metaverse. Adding to this is the recent boom in AR software such as WebAR, which is continuing to strengthen this trend.

The concept of the metaverse is hence the subject of intense and controversial discussion not only in the XR sector, but also far beyond. The topic was therefore addressed in this study. The concept of the metaverse remains somewhat vague, so the widely used definition by venture capital investor Matthew Ball was used as a basis. Ball defines the metaverse as "...a massively scaled and interoperable network of real-time rendered 3D virtual worlds which can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments" *(Ball, 2021).*

German XR enterprises believe that the metaverse has the potential to become very important for their future business. 70 percent of the companies gave the metaverse a score of 5 or higher on a 7-point scale *(cf. Figure 32).* A good quarter of the respondents even assigned the highest rating.

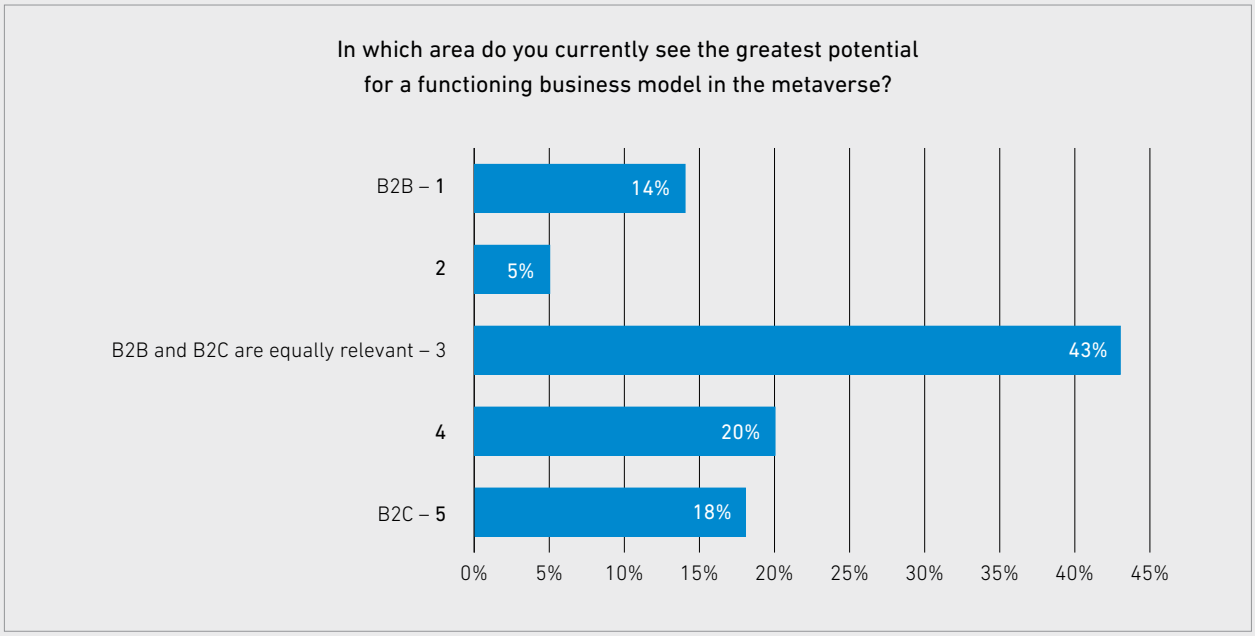
Figure 32: Relevance of the metaverse for the companies' own business in the future



Source: Own data obtained by means of the representative online survey (n=130)

Most of the companies surveyed assume that with the advent of the metaverse, the XR sector's current strong focus on B2B will gradually shift towards B2C markets. Only just under one in five companies (19%) believe that the metaverse will reveal its greatest economic potential primarily in the business sector. By contrast, two fifths (43%) hold that both market categories will remain at least equally important. 38 percent even perceive the metaverse as largely or completely a B2C topic, so that significant shifts in value creation activities would be necessary here.

Figure 33: Business potential of the metaverse

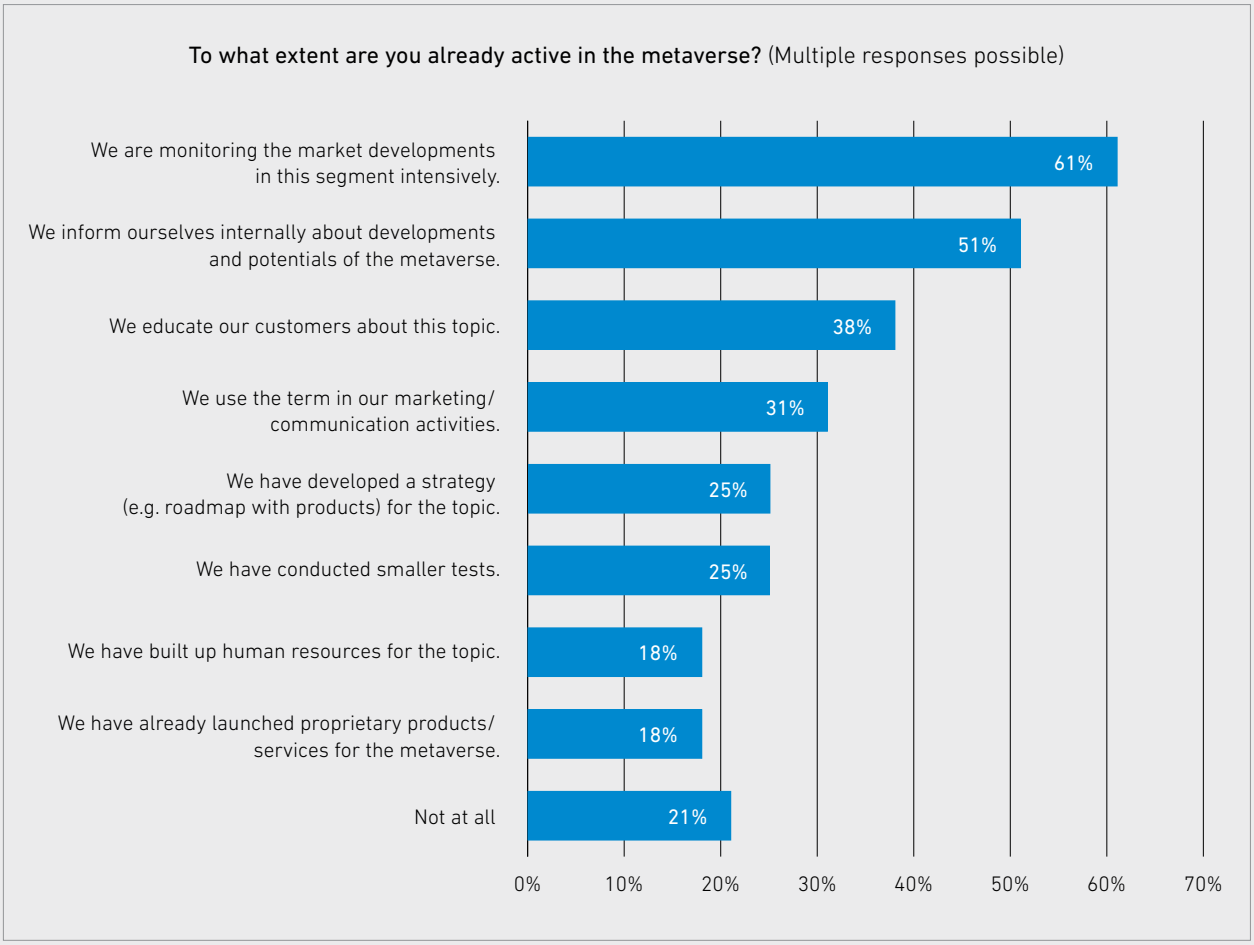


Source: Own data obtained by means of the representative online survey (n=130)

It is therefore hardly surprising that the XR companies have already initiated numerous activities relating to the metaverse *(cf. Figure 34).* Only 21 percent of the enterprises stated that they had done nothing at all. Most frequently, the companies are monitoring current market developments (61%) and keeping their employees informed about the still somewhat abstract concept (51%). However, the companies are already using the metaverse for their own marketing, for instance to educate customers in workshops (38%) or by integrating the term in their corporate communication (31%). Only a smaller proportion of the enterprises have already engaged in entrepreneurial activities. For instance, a respectable quarter have developed their own strategy in regard to the metaverse or have conducted smaller tests, e.g. on individual platforms. The fact that 18 percent of companies have increased their HR

resources for this purpose or are have already launched products in the metaverse (by their own admission at least) is indicative of their belief that the metaverse also presents an opportunity.

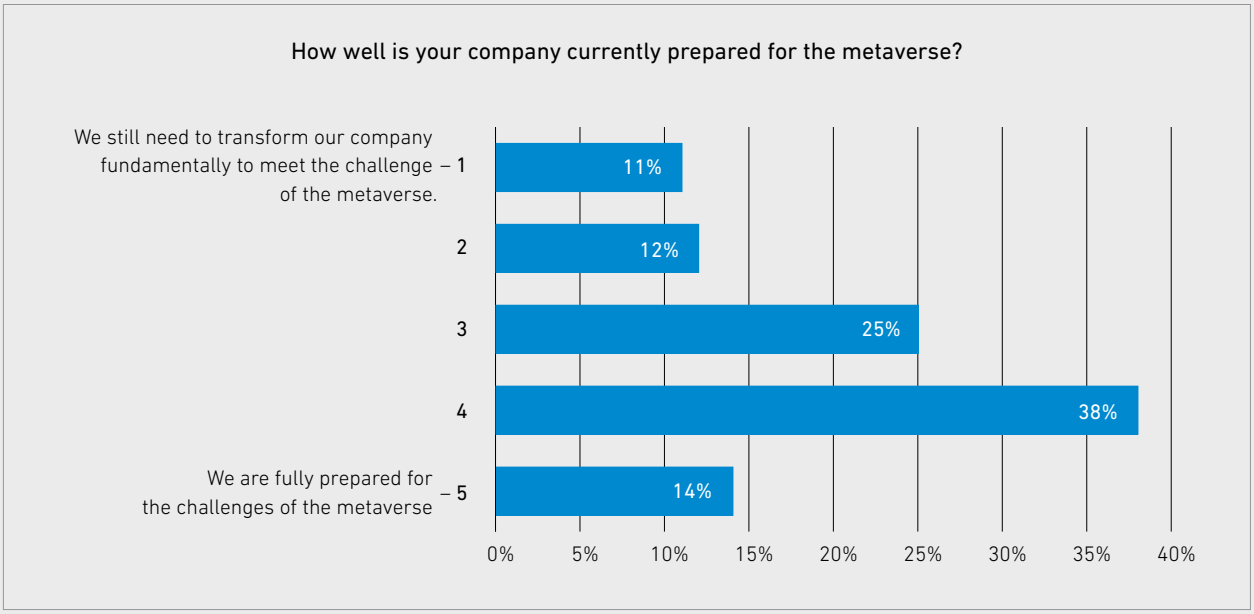
Figure 34: Current activities with regard to the metaverse



Source: Own data obtained by means of the representative online survey (n=130)

The respondents therefore believe that their companies are largely well prepared for the challenges of the metaverse *(cf. Figure 35)* – on average, they rate their level of preparation at 3.3 on a 5-point scale. This is not surprising, as XR enterprises use technologies that are considered important elements in the metaverse. With this in mind, the topic is, to a certain degree, merely an extension of their core business. By contrast, 23% of the enterprises state that they are not at all or barely prepared for the metaverse.

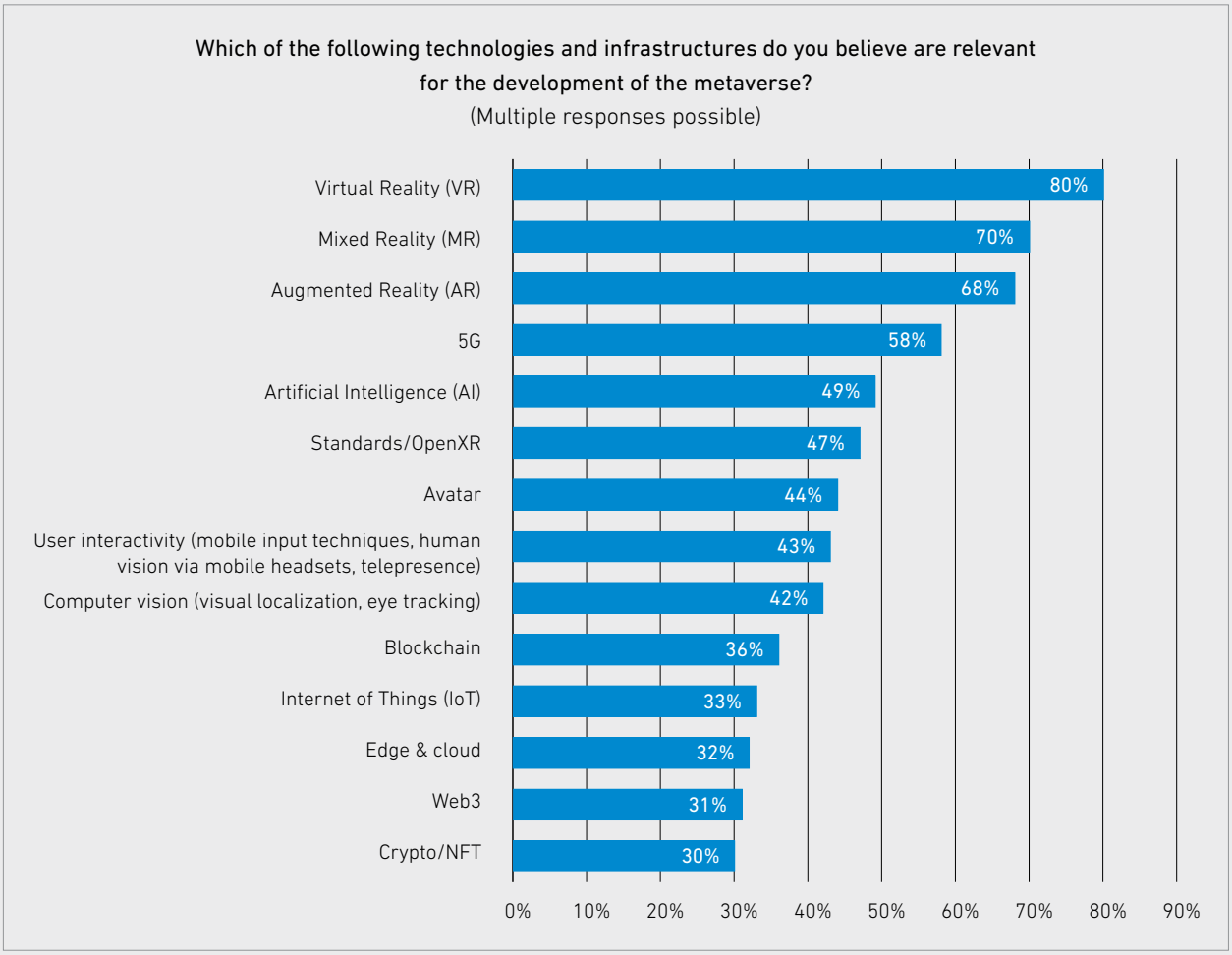
Figure 35: Adaptation of the XR companies to the metaverse



Source: Own data obtained by means of the representative online survey (n=130)

If one believes the various trend analyses and reports, the metaverse will have to combine a variety of nascent technologies in order to unfold its full potential. The respondents assign particular importance to immersive technologies in this context *(cf. Figure 36)*. Virtual reality is mentioned most frequently (80%), ahead of mixed and augmented reality. Most respondents also cite adequate transmission rates via 5G as an important factor (58%). Artificial intelligence (AI) follows with 49 percent, just ahead of the necessity of adopting open standards, e.g. via OpenXR (47%). Several technologies that are required to depict and interact with persons are also mentioned several times. By contrast, relatively few of the respondents see the frequently-discussed 'trend' technologies such as blockchain or cryptocurrencies/ NFT as key technologies for establishing the metaverse.

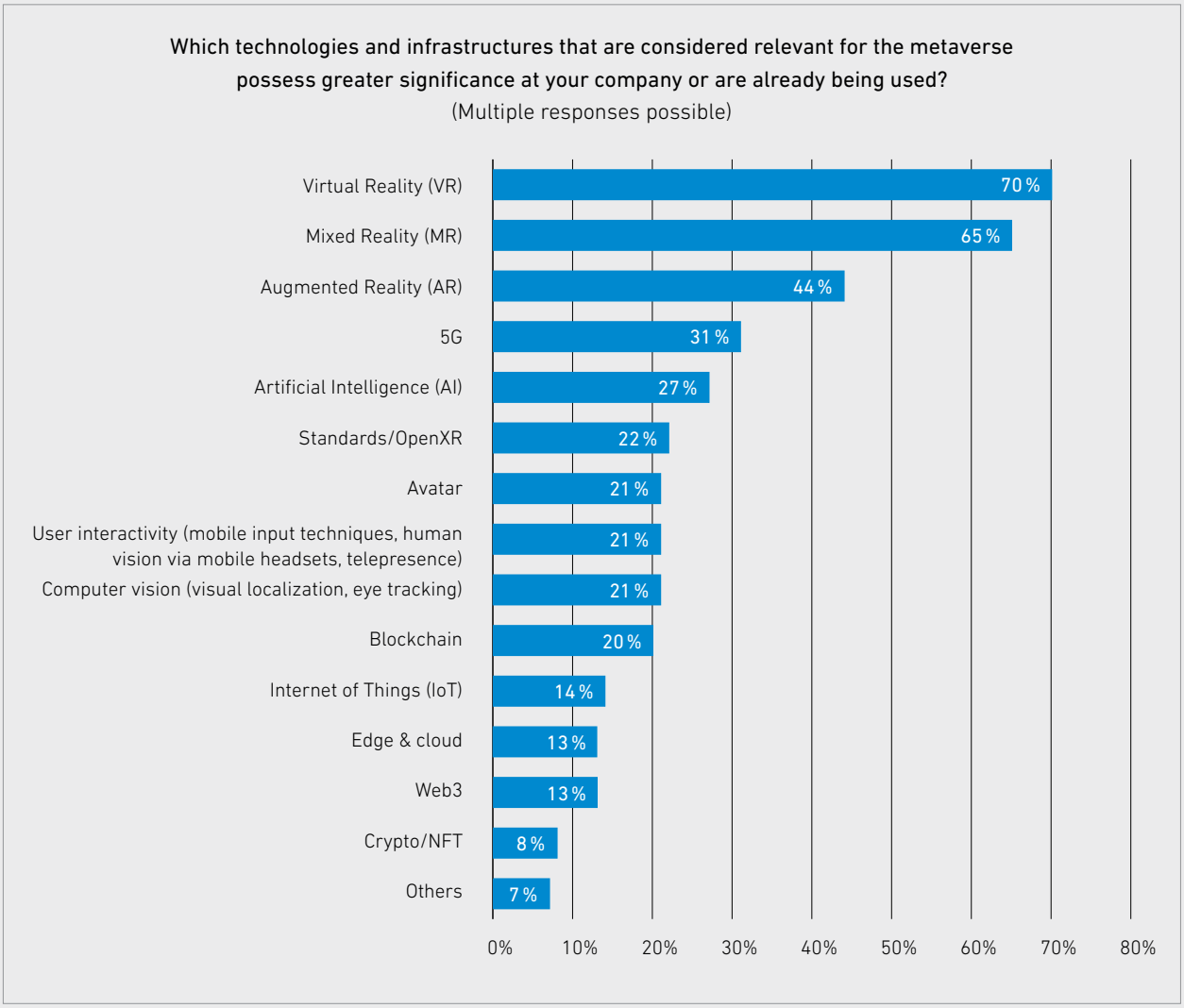
Figure 36: Relevant technologies for the metaverse



Source: Own data obtained by means of the representative online survey (n=130)

Relative to the anticipated significance, many of the XR companies do not use the technologies mentioned above to the same extent *(cf. Figure 37)*. While virtual and augmented reality already enjoy frequent use, the areas of mixed reality and especially 5G/modern transmission technologies are clearly lagging behind. At present, the technologies that are viewed as important for the metaverse are used comparatively rarely overall by the XR enterprises.

Figure 37: Current use of metaverse technologies in XR companies

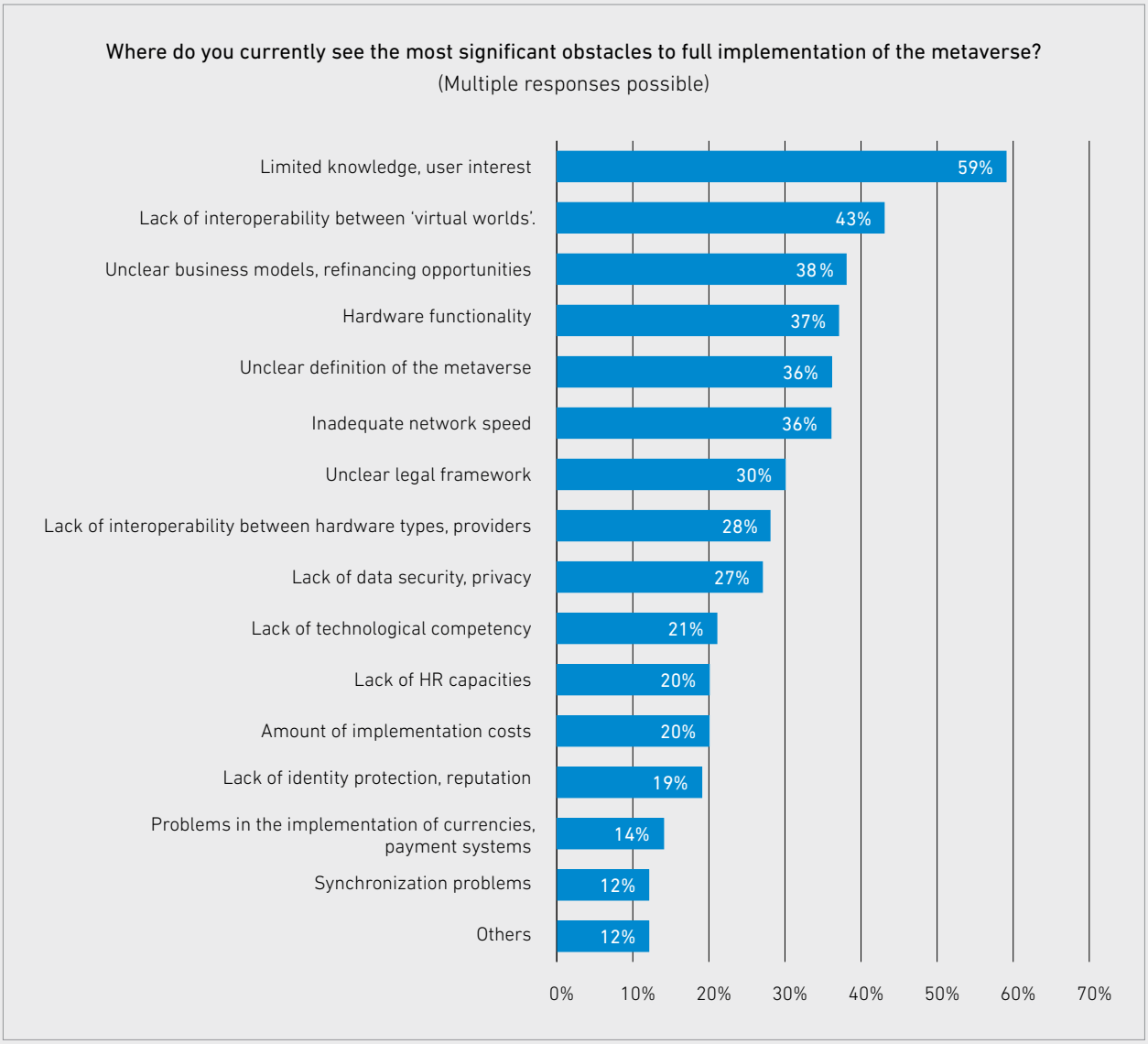


Source: Own data obtained by means of the representative online survey (n=130)

Interestingly, the companies surveyed do not believe that most significant obstacles to establishing the metaverse are found in the technological field *(cf. Figure 38).* Instead – and in line with the findings for the individual XR markets – the current limitations in knowledge among users (59%) or the unclear definition of terms (36%) are viewed as critical. This is, of course, particularly significant if one considers that most enterprises see the greatest potential for the metaverse in the B2C segment at least *(see above).* In second place, however, is the concern that the metaverse might consist of a multitude of isolated individual worlds without interoperability (43%). Moreover, the currently unclear business models and refinancing opportunities are also viewed as obstacles (38%). Inadequate hardware performance (37%)

or insufficient transmission speeds (36%) are mentioned as other significant obstacles to the metaverse.

Figure 38: Obstacles to establishment of the metaverse

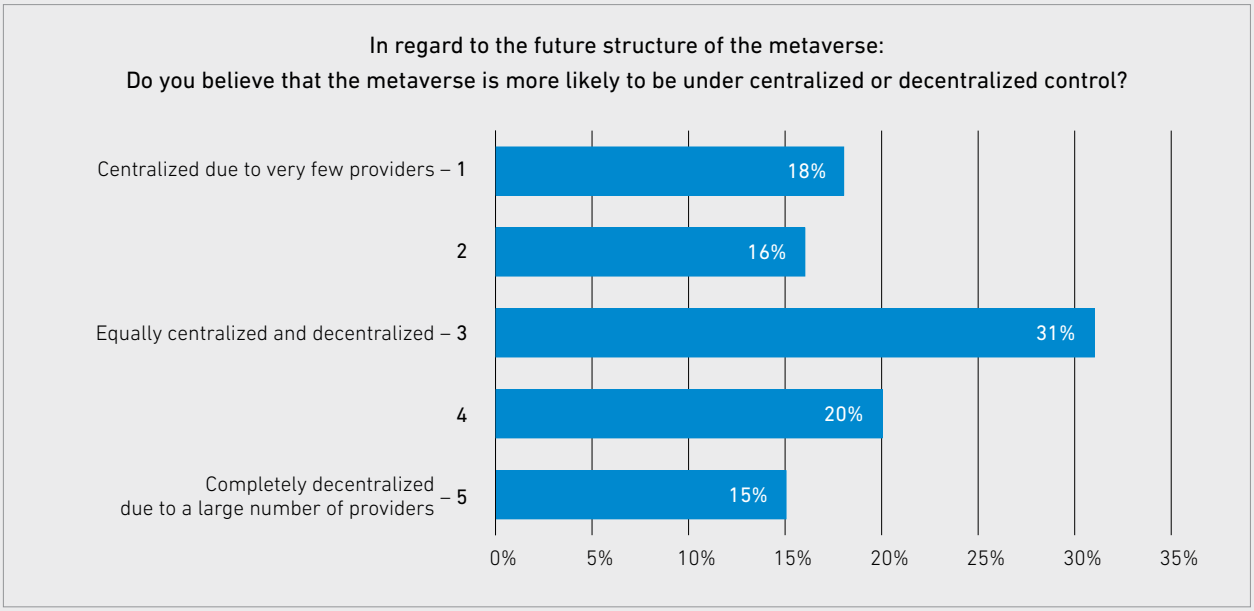


Source: Own data obtained by means of the representative online survey (n=130)

The final question we asked on this topic also addressed the emphasis on a lack of interoperability. There are intense discussions in connection with the metaverse as to the extent to which the individual offerings by companies such as Meta will be mutually compatible or to which degree they will be closed ecosystems. The companies surveyed also returned

an ambivalent assessment. While a good third (34%) assume that a few central providers will – like in other digital markets – dominate this field, a group of about the same size (35%) believes it possible that the metaverse will be decentralized, e.g. via Web3 technologies/ structures.

Figure 39: Expectations for the possible design of the metaverse



Source: Own data obtained by means of the representative online survey (n=130)

7. SUMMARY

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

The XR sector has evolved at a dizzying pace since our first study (at the time exclusively focused on NRW). While there were around 420 companies in Germany in 2017 (extrapolated), we were now able to identify 1,613 companies in the German VR, MR and AR sector in 2022. Many of the companies entered the XR market by expanding the portfolio after their establishment; but startup momentum has remained vigorous over the years, adding approximately 98 companies per year since 2015. Business closures have been relatively rare at the same time. Quite the contrary, many companies are managing to increase their revenue with XR. The number of enterprises generating more than €1 million in this sector has almost doubled since 2021 and is now 16% of all enterprises. This is also a result of the increasing efforts of many players to establish their own platforms and services in order to grow and scale beyond the agency business model.

The sector's burgeoning significance for the national economy is another reflection of this growth. Cumulative gross revenue reached between €490 and €550 million in 2022. Between 12,200 and 12,900 employees now work at the XR companies. Overall, however, it is still a relatively small sector. But it has no need to shy away from a comparison with other high-growth digital sub-sectors: For example, German game developers and publishers are in a similar revenue range as national revenue in influencer marketing (forecast for 2020).

It is interesting to note that while the number of XR employees is experiencing strong growth, the revenue they are generating is rising disproportionately. There is also a greater number of enterprises that make more than €1 million in XR revenue. This points to the increasing significance of platform and scale effects in the production and sales of proprietary products (in contrast to contract manufacturing for individual customers). This underscores the fact that the production of XR software and hardware is becoming increasingly important for German companies. Viewed overall, this leads to considerable specialization and scaling advantages: Large and focused companies are in a better position to profit from opportunities in the XR sector and therefore have a more positive assessment of their possibilities and prospects.

However positive this review undoubtedly is, it demonstrates nonetheless that not even the XR sector can completely detach itself from macroeconomic risks. The overall mood in the XR industry has therefore deteriorated since last year, although the technological foundation, e.g. the devices, are becoming increasingly mature and the trend topic of the metaverse appears set to boost interest in XR. Ironically, the 2021 pandemic was better than expected for the enterprises – and more positive than the assessment of the 2020 pandemic year in the last study *(cf. Chapter 4).* The enterprises therefore weathered the COVID-19 crisis better than was initially expected. But the outlook is now gloomier (albeit still positive). Moreover, many

of the companies rate their current order backlog as inadequate. The hope remains that the detrimental effects of the various economic and political crises will not become even more severe.

Differentiation is also noticeable on the market. For instance, it appears that training applications are becoming established as the most relevant use case (in the B2B segment) across categories for VR, MR and AR. The categories otherwise show varying priorities that are based on the strengths of the individual device types. What all three categories have in common is that information and entertainment offerings are universally rated as less promising, at least for the 18 months ahead. This shows the problematic market situation with low device penetration, but also a lack of distribution and monetization models in this area. The gaming segment is the only exception, which was investigated separately for the first time this year.

The issue of device penetration depends on the one hand on factors such as technical performance and ease of use etc., which continue to improve across devices. On the other, though, competitive prices and a suitable distribution strategy are also crucial. At present, it appears that only the large ecosystem providers possess the necessary power to achieve a breakthrough on the market. Oculus deserves special mention here as the most relevant ecosystem, even for the majority of XR enterprises that focus on B2B. The problematic issues relating to data privacy and the management of B2B partners from the sector are indicative of the potential difficulties in dealing with these large platform companies. This insight is not exactly new and is actually known from other digital markets; but its effects are particularly strong in a small market with a relative paucity of alternative providers. It is therefore not surprising that just under half of the XR companies have adopted a multi-homing strategy in order to secure a broader positioning.

Looking ahead, these issues may acquire an even greater urgency with the next evolutionary stage, the metaverse, as it – according to expectations at least – will target the B2C market as well. The metaverse concept remains highly vague at present and most of the companies surveyed are merely remaining up to date with the topic, explaining it to their customers or using it for marketing purposes. Nevertheless, some enterprises are already offering prototypes and products for the metaverse. User knowledge aside, the interoperability of the various metaverse worlds is viewed as the most significant obstacle for the establishment of the metaverse. A third of the companies expect the major providers to win the race with closed world offerings, although an equally large group is optimistic that at least some degree of openness will prevail.

Ultimately, the findings make clear that the major (non-German) digital corporations are setting the tone, at least in regard to the central platforms and standards etc. Although some of the local XR companies are now generating very substantial revenues and achieving strong growth with their proprietary products and platforms, the big players in this game are currently not from Europe, but from the USA and increasingly from China (due to an aggressive purchasing policy). This competitive weakness, which is known from other digital markets as well, is therefore also reflected in the XR sector. Support for the German sector – e.g. for startups and for scaling and collaboration with other companies – must therefore be provided as a matter of urgency. It is also a purposeful approach in order to take center stage with the various big players going forward.

8. LITERATURE

Prof. Christian Zabel
Prof. Gernot Heisenberg
Daniel O'Brien (M. Sc.)

Ball, M. (Director). (2021). Framework for the Metaverse. https://www.matthewball.vc/all/forwardtothemetaverseprimer

Berg, L. P., & Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: A survey. Virtual Reality, 21(1), 1–17. https://doi.org/10.1007/s10055-016-0293-9

Castendyk, O., Müller, J., Schwarz, M., Wolter, L.-C., & Adam, E. (2021). Die Games-Branche in Deutschland 2018/19/20. Hamburg Media School. https://www.game.de/publikationen/studie-games-branche-in-deutschland-2020/

Chen, L., Yi, J., Li, S., & Tong, T. W. (2022). Platform governance design in platform ecosystems: Implications for complementors' multihoming decision. Journal of Management, 48(3), 630–656.

Goldmedia. (2018). Influencer Marketing in the DACH region. Market Structure, Size and Future Outlook.

Hamari, J., Malik, A., Koski, J., & Johri, A. (2019). Uses and Gratifications of Pokémon Go: Why do People Play Mobile Location-Based Augmented Reality Games? International Journal of Human–Computer Interaction, 35(9), 804–819. https://doi.org/10.1080/10447318.2018.1497115

Hein, A., Schreieck, M., Riasanow, T., Setzke, D. S., Wiesche, M., Böhm, M., & Krcmar, H. (2020). Digital platform ecosystems. Electronic Markets, 30(1), 87–98. https://doi.org/10.1007/s12525-019-00377-4

Huang, H.-M., Rauch, U., & Liaw, S.-S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. Computers & Education, 55(3), 1171–1182. https://doi.org/10.1016/j.compedu.2010.05.014

Kunz, R. E., & Santomier, J. P. (2019). Sport content and virtual reality technology acceptance. Sport, Business and Management: An International Journal, 10(1), 83–103. https://doi.org/10.1108/SBM-11-2018-0095

Kunz, R., Telkmann, V., & Zabel, C. (2021). XR aus Nutzersicht. In C. Zabel, V. Telkmann, & G. Heisenberg (ed.), Cross Reality (XR) in Deutschland: Struktur, Potenziale und Bedarfe der deutschen Virtual Reality-, Augmented Reality- und Mixed Reality-Branche (p. 97–112). Nomos Verlagsgesellschaft.

Lang, S., Dastagir Kota, M. S. S., Weigert, D., & Behrendt, F. (2019). Mixed reality in production and logistics: Discussing the application potentials of Microsoft HoloLensTM. Procedia Computer Science, 149, 118–129. https://doi.org/10.1016/j.procs.2019.01.115

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented reality: A class of displays on the reality-virtuality continuum. Photonics for industrial applications, 282–292.

Peukert, C., Pfeiffer, J., Meissner, M., Pfeiffer, T., & Weinhardt, C. (2019). Acceptance of Imagined versus Experienced Virtual Reality Shopping Environments: Insights from two Experiments. Proceedings of the 27th European Conference on Information Systems (ECIS).

Roth, I., Zanker, C., Martinetz, S., & Schnalzer, K. (2015). Digitalisierung bei Logistik, Handel und Finanzdienstleistungen. ver.di Landesbezirk Baden-Württemberg.

Saunter, T. (2009). Augmented Reality. Digital Cortex. http://digitalcortex.net/tag/table/

Senyo, P. K., Liu, K., & Effah, J. (2019). Digital business ecosystem: Literature review and a framework for future research. International Journal of Information Management, 47, 52–64. https://doi.org/10.1016/j.ijinfomgt.2019.01.002

Federal Statistical Office (Destasis). (2008). Klassifikation der Wirtschaftszweige. Federal Statistical Office (Destatis).

Zabel, C., & Telkmann, V. (2021). The adoption of emerging technology-driven media innovations. A comparative study of the introduction of virtual and augmented reality in the media and manufacturing industries. Journal of Media Business Studies, 18(4), 235–266. https://doi.org/10.1080/16522354.2020.1839172

Zabel, C., & Telkmann, V. (2022). The role of location for non-focal firms in emerging digital business ecosystems. Relevance of agglomeration factors in the German XR industry. In S. Baumann (Ed.), Handbook on Digital Business Ecosystems: Strategies, Platforms, Technologies, Governance and Societal Challenges (p. 250–268). EDWARD ELGAR.

Zabel, C., Telkmann, V., & Heisenberg, G. (2021). Cross Reality (XR) in Deutschland: Struktur, Potenziale und Bedarfe der deutschen Virtual Reality-, Augmented Reality- und Mixed Reality-Branche (1st edition). Nomos.

Minister für Bundes- und Europaangelegenheiten,
Internationales sowie Medien
des Landes Nordrhein-Westfalen
und Chef der Staatskanzlei

EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds
für regionale Entwicklung

EFRE.NRW
Investitionen in Wachstum
und Beschäftigung

Mediennetzwerk.NRW is financed by the State of North Rhine-Westphalia and with funds from the European Regional Development Fund (ERDF).