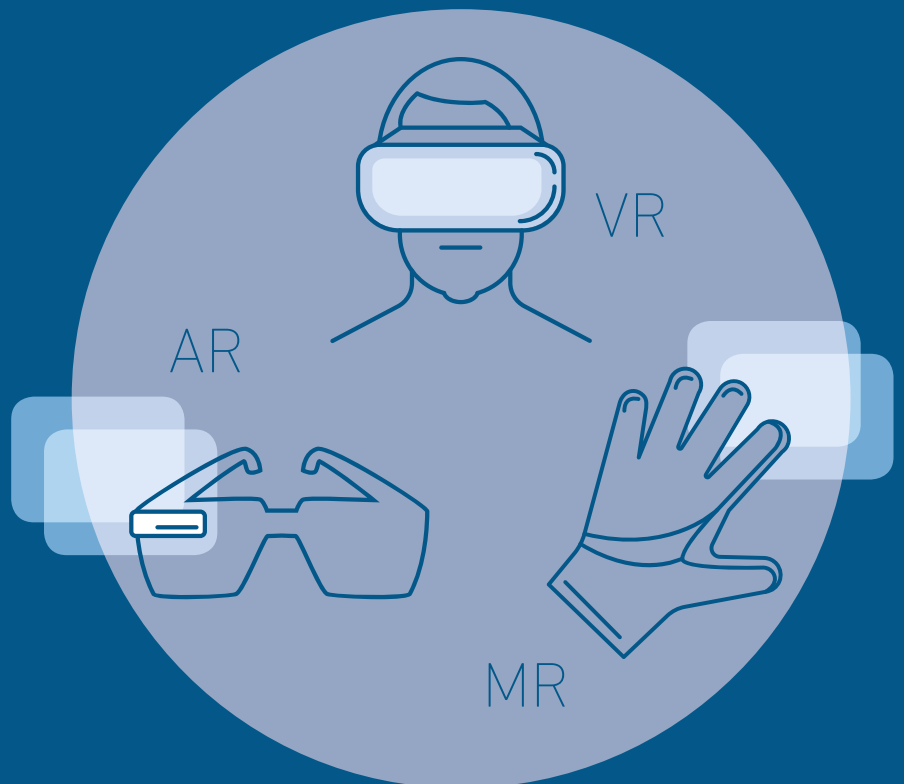


Virtual, Mixed & Augmented Reality in NRW

Potentials and needs of the VR, MR, AR sectors in
North Rhine-Westphalia



Technology
Arts Sciences
TH Köln

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Mediennetzwerk.NRW supports media companies in North Rhine-Westphalia in exploiting the opportunities of the digital transition and in establishing national and international networks. It is financed by the State of North Rhine-Westphalia and with funds from the European Regional Development Fund (ERDF).

Die Landesregierung
Nordrhein-Westfalen



EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds
für regionale Entwicklung



EFRE.NRW
Investitionen in Wachstum
und Beschäftigung

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on Behalf of Mediennetzwerk.NRW**

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Table of Contents

0. EXECUTIVE SUMMARY	6
0.1. Study Design	7
0.2. General Development of the Sector	7
0.3. Opportunities and Challenges for VR	7
0.4. Opportunities and Challenges for AR and MR	8
0.5. The Structure of the VR/MR/AR Sector in NRW	9
0.6. Customer and Revenue Structures	9
0.7. Evaluation of the NRW Location	10
0.8. Development Needs of the Sector	11
0.9. Recommendations for Action	11
1. PROBLEM & OBJECTIVE SETTING	13
1.1. Initial Position	14
1.2. State of Research	15
1.3. Research Design	17
2. DELIMITATION OF VIRTUAL, MIXED AND AUGMENTED REALITY	20
2.1. Technical Delimitation	23
2.2. Industrial Economic Structure of the Sector	26
2.2.1. Breakdown based on the Value Chain	27
2.2.2. Breakdown by Markets	29
3. THE MARKET FOR AUGMENTED, VIRTUAL AND MIXED REALITY IN GERMANY	33
3.1. Sales Performance in Germany	34
3.2. Use of VR, MR and AR in Germany	39
3.3. Opportunities and Challenges of the VR/MR/AR Sector	40
3.3.1. Possible Use Cases for VR	40
3.3.2. Possible Use Cases for AR and MR	44
3.3.3. Challenges for the Adoption of VR	46
3.3.3.1. End Devices: Distribution, Use, Usability, Performance	49
3.3.3.2. Standards and Interoperability	50
3.3.3.3. Monetization	50
3.3.3.4. Conceptual Design	51
3.3.3.5. Design of the Value Chain	52

3.3.4.	Challenges for the Adoption of MR and AR	53
3.3.4.1.	Technology	54
3.3.4.2.	Regulatory Requirements	55
3.3.4.3.	Economic Requirements	55
4.	NATIONAL AND INTERNATIONAL BEST PRACTICES	57
4.1.	Selected VR Cases	58
4.1.1.	Better than Life / Deutsche Telekom AG	58
4.1.2.	My Brother's Keeper / PBS	58
4.1.3.	Opel "Adam" – Germany's Next Top Model	58
4.1.4.	MIYUBI / Felix & Paul Studios	59
4.1.5.	Carne y Arena / Alejandro Gonzalez Iñárritu	59
4.1.6.	The Void Star Wars Challenge	59
4.1.7.	Home – A VR Spacewalk / Rewind	59
4.1.8.	The Cathedral / WDR	60
4.1.9.	Safran Nacelles and Airbus	60
4.2.	Selected AR and MR Cases	61
4.2.1.	Augmented Reality Maintenance / Deutsche Telekom AG	61
4.2.2.	Augmented Reality Shopping / Yihaodian	61
4.2.3.	Project Esper / 3D4Medical	61
5.	THE VR AND AR SECTOR IN NRW	62
5.1.	Structure of the VR/MR/AR Sector in NRW	63
5.2.	Activities of VR/MR/AR Companies in NRW	68
5.3.	Customers and Revenues of VR/MR/AR Companies in NRW	72
5.4.	Development of the NRW Location	77
5.4.1.	Significance and Evaluation of the Location from the Stakeholders' Perspective	77
5.4.2.	Development Needs in NRW from the Stakeholders' Perspective	80
6.	DERIVATION OF RECOMMENDATIONS FOR ACTION	84
6.1.	Stronger Networking with Universities and Research Institutions	85
6.2.	Training of Specialists at the Location	85
6.3.	Regional Networking with Customers	86
6.4.	Stronger Networking within the Sector	87
6.5.	Dedicated Support Measures for Media-related Productions	88
7.	LITERATURE	89

List of Figures

Figure 1: List of interview partners	19
Figure 2: The Reality-Virtuality/Mixed Reality Continuum	21
Figure 3: Mixed Reality Scale according to Tom Saunter	22
Figure 4: Various Head-Mounted Display Systems (HMD)	24
Figure 5: CAVE as Rear Projection-based Virtual Reality Display	25
Figure 6: Projection-based Augmented Reality Solutions	26
Figure 7: Integration of Value Creation Stages in the B2C VR Market	27
Figure 8: Value Creation Chains for VR-AR Projects	28
Figure 9: Target Market Content Matrix for Virtual and Augmented Reality	30
Figure 10: Suitability of AR/MR/VR Types for Use Cases	32
Figure 11: Worldwide VR Sales, 2014-2018	34
Figure 12: Virtual Reality Sales in Germany, 2016-2020	35
Figure 13: Development of B2B Sales in Germany, 2016-2020	37
Figure 14: Long-term Business Models in the VR/MR/AR Market	38
Figure 15: Assessment of the Attractiveness of VR Use Cases in the Next 18 Months	41
Figure 16: Assessment of the Attractiveness of AR and MR Use Cases in the Next 18 Months	45
Figure 17: Factors for the Adoption of VR	47
Figure 18: Factors for the Economic Development of VR	48
Figure 19: VR Along the Consumer Electronics Value Chain	53
Figure 20: VR Along the Consumer Electronics Value Chain	54
Figure 21: Regional Distribution of VR/MR/AR Companies in NRW	63
Figure 22: Regional Distribution of VR/MR/AR Companies in NRW (survey)	64
Figure 23: Size Classes of VR/MR/AR Companies in NRW	65
Figure 24: Distribution by Size Class and Region	66
Figure 25: Founding Dates of VR/MR/AR Companies in NRW	67
Figure 26: Legal Forms of VR/MR/AR Companies in NRW	68
Figure 27: Activities in VR, MR and AR	69
Figure 28: Product Portfolio of VR/MR/AR Companies in NRW	70
Figure 29: Formats Offered by VR/MR/AR Companies in NRW	71
Figure 30: Target Industries of VR/MR/AR Companies in NRW	73
Figure 31: Annual Sales by VR/MR/AR Companies in NRW 2016	74
Figure 32: Satisfaction with Current VR/MR/AR Activities	75
Figure 33: Satisfaction with VR/MR/AR Activities in 18 Months	76
Figure 34: Importance of a Specific Location for the Success of VR/MR/AR Activities	77
Figure 35: Geographical Focus of Corporate Activities	78
Figure 36: Geographical Focus of Corporate Activities	79
Figure 37: Development Needs from the Perspective of VR/MR/AR Companies	80

0. EXECUTIVE SUMMARY

0.1. Study Design

- The design of the study combines several investigation steps: Desk research, complete survey and online survey of virtual reality (VR) / mixed reality (MR) and augmented reality (AR) companies in NRW as well as interviews with experts.
- The focus of interest is on trends, potentials and risks in the VR/MR/AR industry, the structure and development of the industry in NRW and the need for support measures.
- A total of 101 VR/MR/AR companies in NRW were identified, 43 of which took part in the online survey. The sample is representative in terms of location, company age and size. In addition, 13 experts from different sub-areas of the VR/MR/AR industry were interviewed.

0.2. General Development of the Industry

- Forecasts predict strong growth in the VR/MR/AR industry: According to PWC, VR alone is expected to generate sales of over €1 billion in the German consumer market in 2020. According to estimates by Deloitte, the B2B segment for VR/MR/AR applications could amount to €840 million in Germany in 2020. However, the growth achieved in the industry has recently lagged behind these forecasts.
- In the medium term, AR and possibly MR are expected to represent the larger share of the market. However, in the short term, experts attribute higher relevance to VR.

0.3. Opportunities and Challenges for VR

- Over the next 18 months, the NRW companies see potential primarily in B2B applications in the area of training, e.g. for employees (83% of respondents) and in the area of design/simulation, e.g. for the development of prototypes (77%). With regard to end customers, information/entertainment (65%) and product presentations/experiences, e.g. at the point of sale, but also in the event trade show sector (62%), are regarded as promising.
- In addition to games, media-related applications will primarily include 360° videos, volumetric (i.e. holographic) and interactive videos. It is expected that moving image content will increasingly be produced in addition to linear film and TV productions.
- However, the implementation of VR faces several challenges. These include, above all, devices that are not yet sufficiently powerful or easy to use, especially in the case of dis-

play systems. In addition, the knowledge, dissemination and actual use of the systems is currently too low.

- Other deficits identified include a lack of standards and interoperability of systems and applications as well as a lack of monetization models (beyond B2B applications). In addition, conceptual hurdles still have to be overcome, for example in the area of user interaction and narration.
- Finally, the structure of the sector with a small number of providers controlling the central platforms is seen as problematic for its profitable development in the long term.

0.4. Opportunities and Challenges for AR and MR

- In the AR and MR field, NRW companies expect the training of employees (68%) and supportive deployment in production/maintenance/service (65%) to be the most common fields of application. Design/simulation (56%), experience/product presentations (53%) and support systems/navigation aids (53%) are also rated as attractive.
- Similar deficits are identified in the AR and MR segments as in the VR segment. First and foremost among them is the inadequately mature technology for the mass market, especially in the MR segment. Many devices (HoloLens etc.) are too expensive and currently not powerful enough for widespread use (also in the B2B sector). In addition, challenges are seen in data processing and data transmission especially.
- For 'low-end' AR applications, the smartphone provides an extensive device base. Here, it is expected that rapid development of new applications will begin using Apple and Google's AR software developer kits.
- In addition to structural regulatory requirements, MR and AR providers in the consumer segment also face the economic challenge of establishing value creation models.

0.5. Structure of the VR/MR/AR Sector in NRW

- The sector in NRW displays a strong regional concentration: 46 of the 101 companies have their registered offices in Cologne or Düsseldorf. Other important centers are Aachen (7) and Bonn (5).
- Most companies are also rather small: A third of them have less than ten employees, another quarter less than 50.

- The number of VR/MR/AR startups has accelerated: A good quarter of the companies were founded in the last three years. However, many companies are more than ten years old, so they were already involved in 'earlier waves' of VR.
- The companies are primarily active in the VR sector (91% of respondents; AR: 71%, MR: 50%). The boundaries between the three offered forms are becoming blurred: 40% of the companies were active in all three fields.
- With regard to the products and solutions currently sold, information and entertainment offerings, e.g. news videos or games, are ahead (59%). Experiences/product presentations were also frequently mentioned, before design/simulation (56%) and training (54%). Applications in the areas of manufacturing/maintenance/service (29%), conferencing (20%) or support systems (10%) are developed and sold much less frequently.
- In terms of product forms, moving image content (360°, interactive or volumetric videos) is the most common (63%), followed by product presentations (48%) and prototypes (43%), followed by games (30%) and serious games (23.5%).

0.6. Customer and Revenue Structures

- NRW companies most frequently work for the media/information and communications sector (here primarily for film and television) and the manufacturing industry (46% each). This is followed by hospitality/tourism (32%), science & research (27%), medicine/health-care and arts & entertainment (24% each).
- Almost half (49%) of the companies surveyed generated less than €100,000 with VR/MR/AR in 2016, 11% of them less than €20,000. Notwithstanding, 29% of the companies reported VR/MR/AR-related sales of more than €100,000, but less than €1 million. Three companies realized sales volumes of over €2 million with VR/MR/AR.
- The companies are rather satisfied with their VR/MR/AR-related business development (value of 2.63 on a five-level Likert scale with 1 = very satisfied to 5 very dissatisfied). The assessment is therefore more cautious than the public discussion surrounding VR/MR/AR would suggest.
- However, the companies expect a significant improvement in the business prospects in the next 18 months (value of 2.06, same scale).

0.7. Evaluation of the NRW Location

- Only 40% of the companies surveyed generally assign an important or very important role to the location of their company for the success of VR/MR/AR activities. By their own admission, the companies are nationally or internationally oriented in most areas of their activities (customer acquisition, integration of suppliers, research facilities, etc.). The exception is the recruitment of new employees, which takes place primarily at regional level.
- For the specific location of North Rhine-Westphalia, good access to potential employees is rated as important (value of 1.97 on a five-level Likert scale from 1 (very important) to 5 (absolutely unimportant)). This is followed by access to customers in the region (2.08) and to freelancers for individual projects (2.21), networking with other local VR companies via meetings and conferences (2.26) and the regional exchange of information via groups, events or associations (2.28).
- Proximity to the creative and media industries is also regarded as significant (2.38). For the companies based in Cologne, this is the most important factor (1.65).
- Also of relevance are proximity to research institutions (2.54), location promotion (2.64), proximity to technical service providers (2.77) or other companies in the sector (2.82).
- For companies less than three years old, proximity to other startups (2.54) also plays an important role.

0.8. Development Needs of the Sector

- Initially, the intensification of cooperation between universities/research institutions and industry is considered to be a priority (58%), including stronger cooperation in calls for tender in scientific research projects with practical relevance. At the same time, universities are important for recruiting employees (see above).
- 50% also see better regional networking with customers in the B2B environment as a priority. First of all, the concrete knowledge of the application possibilities of VR/MR/AR for 'first-time buyers' should be promoted, as should networking with customers already active in this field.
- Exactly 50% would also like to see an expansion of education and training. Overall, the training opportunities in NRW are good, but there are bottlenecks, for example with 'creative coders' or Unity/Unreal developers. In view of this rapid development, offers for further vocational training of employees are also necessary.
- Finally, networking among companies (37%) and improved lobbying by industry associations are also considered important. Here, other locations such as Berlin or Hamburg are currently perceived to be more effective. Ideally, initiatives in this respect would not only consider individual cities, but also regions (especially Cologne-Düsseldorf) and other value-added areas (e.g. the European region of Aachen/Belgium/Netherlands).

0.9. Recommendations for Action

- **Stronger Networking with Universities and Research Institutions** This could be achieved by creating a forum modeled on the example of VDC Fellbach or the AVARE network in Chemnitz, which brings together users, suppliers and research institutions. First initiatives already exist here (e.g. at RWTH Aachen University). An expansion should reflect the varied structures of the regional value-added areas.
- **Training of Specialists at the Location:** At first, the development of part-time training as a 'Digital Producer' (especially with regards to media-related production) seems to make sense. In addition, film and media students could be made more aware of the potential of the medium during their studies, e.g. via pop-up movie theaters or VR arcades. Finally, the establishment of a stronger cross-organizational exchange on specific specialist topics (possibly in the context of established industry events, see below) could help to promote

the acceptance and use of VR/MR/AR in companies themselves.

- **Regional Networking with Customers via a Multi-step Approach:** First, low-threshold 'evangelization' should be intensified through information events and programs, e.g. through chambers of industry and commerce or industry associations. Test labs and viewing rooms should be created for initial collaborations/demonstrations. A model here is the XR Lab of the Digital Hub in Cologne or the planned Center for Immersive Technologies at the Cologne Game Lab/TH Cologne. The third element that is recommended is the targeted contacting of customers at events and trade shows. In this respect, the establishment of a leading regional trade show on the subject is advisable; the first steps have already been taken with the Digility Conference. Finally, it would be worth considering strengthening visibility by establishing a prize with international appeal, e.g. as part of the German Developer Award or the leading trade show.
- **Networking within the Sector:** Here, people should first be made more aware of low-threshold offerings (e.g. meetups) of existing initiatives, with the addition of thematically focused opportunities for professional exchange in the sense of a 'community of practice'. It is also advisable to set up a regionally focused industry association that will attract attention and act as a forum for professional exchange and networking with science and customers.
- **Dedicated Support Measures for Media-related Productions:** While functioning value-added systems have already emerged in industrial applications, this applies only to a very limited extent to media-related VR/MR/AR applications. It would therefore be worth considering the introduction of a targeted support system to help productions or companies that are active in this field. This requires the creation of suitable framework conditions for substantial, targeted and efficient support measures in the various sub-areas that are relevant to VR/AR. For example, the NRW Film and Media Foundation's support program for digital content, which has been running since 2011, would provide a suitable program in this sense, although it would require access to greater funding. In addition, media-related support could address content-specific consulting needs that 'general' incubators, co-working spaces, etc. can only accommodate to a limited extent. This could be achieved, for example, through a dedicated specialist program on VR/MR/AR-specific aspects of media production and distribution.

1. PROBLEM & OBJECTIVE SETTING

1.1. Initial Position

VR and MR applications have been the focus of companies working on innovative content and services since the release of the first Google Glasses in 2012. These range from virtual fitness applications, immersive games and film experiences to virtual showrooms and simulators for training purposes. In the same way, augmented reality (AR) applications have triggered storms of enthusiasm since the release of Pokémon Go and made mass use possible.

However, these technical approaches are nothing new. The beginnings of the technology go back to the first Head-Mounted Displays (HMD), which came from military research in the early 1990s and made industrial applications possible. The fact that this technology only made the leap into use within the industry is due to the high costs for the necessary computer technology at the time and the significant know-how requirements for operation, as well as the low wearing comfort of the HMDs. The resulting rear projection-based systems such as CAVEs and responsive workbenches, on the other hand, have at least contributed to the spread of VR technology within the global automotive and aerospace industries. The VR technology of the time never really made the leap into other industries.

AR applications have been researched very intensively in the context of national funding projects such as ARVIKA since their emergence at the beginning of the 2000s at the latest, and their application in the field of simulation and support of industrial maintenance tasks has been evaluated. (*Friedrich, 2004*). Here, too, the beginnings of AR technology were unsuited to the mass market due to their elaborate use and high costs.

With the advent of powerful and easy-to-use smartphones, VR/AR technology now appears to be suitable for the mass market:

- With the aforementioned Pokémon Go, Google CardBoard as an output device or various VR gaming systems, popular applications for the masses are successful in the market.
- In addition, companies see enormous potential in raising their customer communication to a new level. Various companies would like to use VR/MR/AR and offer their customers new 360-degree experiences.
- Both technologies are also suitable for the preparation of media content – a number of high-quality showcases and applications have already been created so far.
- Finally, VR and AR systems can be used to increase productivity and organize workflows more efficiently (e.g. in production, maintenance of complex machines).

As a result, in addition to established players, numerous new companies have been set up in Germany and especially in NRW to satisfy the strong rise in demand for VR/MR/AR content and services. However, this growth opportunity for the (media) economy in NRW has not yet been investigated. Thus, apart from anecdotal evidence, it is not known which companies are actually working on these technologies, which competences are available at the location and, above all, what demands exist with regard to qualification, promotion and networking. These questions form the core of this study.

The client is the Mediennetzwerk [Media Network] NRW. The research is dated from November 30, 2017.

1.2. State of Research

The present study can be classified as research on (media) clusters – a field that has generated sustained scientific interest in recent years. (*Boix, Hervás-Oliver, & De Miguel-Molina, 2015: 753*). A cluster can be fundamentally described as “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (*Porter, 1990: 16*).

Three fundamental reasons for the emergence of successful media clusters are discussed in the literature (*Moomaw, 1988*):

- Urbanization advantages that arise from a ‘media-appropriate’ environment (culture, nightlife, living space, etc.).
- Agglomeration advantages resulting from the proximity of companies to one another (e.g. synergies/production networks, local talent pools)¹.
- Localization advantages that arise from the binding of companies to a specific location (e.g. connection to studio infrastructure or central anchor companies in the industry).

Today, with a view to the media industry, numerous case studies are available discussing the success factors of individual clusters (for an overview, see *Komorowski, 2017*). The significance of the individual factors varies depending on the sub-sector under consideration (e.g. audiovisual media, new media, creative industry or print media), although media convergence

¹ For example, a high density of companies, numerous suppliers and local customers all contribute to the success of startups. (*Pe'er & Keil, 2013*).

is making it increasingly difficult to distinguish between them. (Achtenhagen & Picard, 2014).² Therefore, approaches that are based on industrial cluster research (Markusen, 1996) are more promising when they focus on the dominant processes that shape the cluster (Gordon & McCann, 2000).

The small and medium-sized (audiovisual) media companies in particular tend to benefit from geographical proximity in a cluster, which facilitates personal exchange, for example in the acquisition, recruitment or transfer of 'tacit knowledge'. (Blackburn & Conway, 2008). This is especially true since media content is mainly produced on a project-by-project basis. However, it is crucial that companies are not only close to one another. The effect of the cluster depends to a significant degree on the intensity of the interactions within the group (Virta & Lowe, 2017: 15). Here, the strength, connections and dependencies of the nodes within the value creation network are particularly crucial (Håkansson & Ford, 2002).

The example of the creative industries also shows that individual sectors can often be found at the same locations – this applies in particular to the film, video/music, software, culture, video games, design, construction and architecture sectors. Finally, regional clusters can work across countries (for an analysis at the European level based on business data, see (Boix et al., 2015)).

The view 'from the industry perspective' is also particularly important for companies in the 'new media' sector. In the literature, it is assumed here that these work more strongly across regions: "(they) do not have the well-defined but disintegrated production functions upon which local concentration could be built" (Achtenhagen/Picard 2014: 230). In their study of German multimedia clusters, Fuchs and Koch, for example, show that proximity to key customers from the media industry was more important than the emergence of cooperative networks between multimedia companies. (Fuchs & Koch, 2005). In the case of new media clusters in Dublin and Sussex, on the other hand, no such effects could be demonstrated for new media companies. (Bayliss, 2007; Blackburn & Conway, 2008).

1.3. Research Design

The state of research suggests that the factors for the establishment of new media companies – including VR and AR companies – may differ from those in 'traditional' sectors. In

² Komorowski proposes a definition of media clusters according to the seven criteria – place, proximity, population, profile, path-dependency, policy, performance (Komorowski, 2017)

In addition to a description of the virtual and augmented reality industry, it is therefore necessary to examine separately which aggregation factors play a special role for companies.

All in all, a three-step analysis is to be carried out in this way. The first part examines how companies assess the long-term attractiveness of the VR and AR market. For this purpose, the companies will be asked about expected trends and strategic perspectives. Then, in a second step, it can be asked which specific expectations and requirements of the location exist. The findings can then provide important information for the further development of public sector support measures. The following three questions are to be posed:

Q1: What is the status quo of the VR/AR sector in NRW and what are the strategic development perspectives (trends, potentials, risks) from the point of view of the market participants?

Q2: How important are agglomeration, localization and urbanization effects for the choice of location and the success of companies in the VR/AR sector?

Q3: What concrete funding/support needs are there in the industry? What measures could be suitable, specifically for NRW as a business location?

In order to be able to answer the questions, the key players in the North Rhine-Westphalian VR/AR sector were identified by means of own research (desk research). The companies were then interviewed using a standardized online survey on activities, industry focus, company data, strategies, perspectives and needs. In addition, guided expert interviews were conducted with 13 selected institutions in order to obtain high-quality primary material on strategies and needs as well as current and future VR, MR and AR cross-sectoral topics.

The units of the population were recorded by means of manual research and modified snowball sampling, since no registers or similar exist for this area. For this purpose, special search tables with search terms linked by Boolean operators, which were also subjected to a synonym check and an English translation, were used. If companies were identified in NRW, the company's website, Wikipedia entries, any job advertisements on industry portals, etc. were analyzed in closer detail in a subsequent step.

In addition to researching general information on the company (registered office, legal form, year established, management, number of employees), the target industries and the forms of VR/MR/AR offered were surveyed. A total of N=101 companies were identified and analyzed. Thus, the basic population in NRW was surveyed as completely as possible.

The survey of all companies in the population was then carried out in a second step using a standardized online questionnaire. The field phase of the survey ran from November 6 to 30, 2017. The companies were asked to take part in the survey in three waves. A total of 43 organizations responded,³ which corresponds to a pleasingly high response rate of approx. 43%.

Thirdly, selected industry experts and company representatives were interviewed for the study (see *Figure 1*). The survey was conducted mainly in personal interviews, partly by telephone on the basis of a partially structured interview guideline. The interviews were conducted in October and November 2017 and lasted an average of 40-60 minutes.

³ The gross figure of 44 responses had to be adjusted for an organization that did not provide any usable data.

Figure 1: List of Interview Partners

Name & Function	Position	Company
Clarissa Kyrion	Marketing & Partnership Manager	VIRE GmbH
Thomas Hallet	Innovation Lab Director	WDR
Frank Heineberg, Senior	Manager Program Distribution	CBC/RTL Group
Eckhardt Köberich	Head of VR	ZDF Digital
Maik Herrmann Dirk Krause	Client Service Director; Innovation Lab Director	Pixelpark AG
Ulrike Stemmer	Senior Strategic Planner	Denkwerk GmbH
Prof. Torsten Kuhlen	IT Center of RWTH Aachen, Director	RWTH Aachen
Boris Kantzow	Managing Director	Weltenmacher GmbH
Arne Ludwig	President	EDFVR e.V.
Michaela Dierking	Managing Director	Virtalis GmbH
Kristian Costa-Zahn	Head of Creation	UFA Lab
Stephan Heininger	Virtual Reality Director	Telekom Deutschland GmbH
Prof. Björn Bartholdy	Co-Director Cologne Game Lab	Cologne Game Lab

Source: Own research

2. DELIMITATION OF VIRTUAL, MIXED AND AUGMENTED REALITY

Reifinger defines the distinction between Virtual Reality (VR) and Augmented Reality (AR) as follows: “While VR completely separates the user from their real environment and replaces it with a virtual environment, AR expands the user's real environment by adding a virtual environment” (Reifinger, 2008: 10).

This definition is helpful, but the question arises as to whether this boundary should always be drawn so sharply. Based on this question, 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, Takemura, Utsumi, & Kishino, 1995). This has now become an agreed standard. Figure 2 shows the different terms and expressions in a so-called mixed reality continuum.

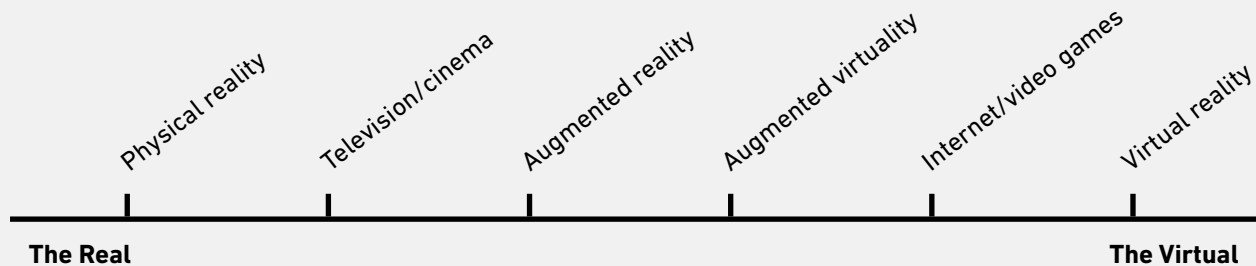
Figure 2: The Reality-Virtuality/Mixed Reality Continuum



Source: According to Milgram et al., 1995

The so-called mixed reality scale by Tom Saunter – a simplified version of the virtuality continuum – is helpful to better classify the current media forms (see Figure 3).

Figure 3: Mixed Reality Scale according to Tom Saunter



Source: <http://digitalcortex.net/tag/table>

In simple terms, Saunter distinguishes between the real and virtual worlds and shows where television and cinema as well as the Internet and video games fall on the scale. This approach is very useful when attempting to classify current media forms. Television and movies are digitally recorded versions of the real world, whereas Internet sites or video games are completely virtual. The difference from virtual reality lies in the fact that in virtual reality, the feeling of immersion is conveyed. Immersion is the illusion of being part of a virtual world. On the Internet or in video games, this immersion can only be experienced to a very limited extent, if at all. This delimitation disappears somewhat with the latest technology, but an unbridgeable gap remains fundamentally on the immersion level.

This study focuses on the VR (virtual reality) and AR (augmented reality) media forms. The mixed forms are recorded accordingly in MR (mixed reality).

2.1. Technical Delimitation

The terms 360° and virtual reality are not sufficiently distinguished in literature and especially on the web. However, they should be differentiated in the context of this study in order to allow for a meaningful evaluation, since the production and use of the media types differ greatly. This distinction results in different needs with regard to qualification and technological promotion.

360° videos are produced with real (e.g. concert recordings, nature films) or animated content (e.g. the virtual reconstruction of Cologne Cathedral). In addition, there is often free spatial movement. This is relatively easy, especially with animated content. For 360° videos with real content, perspectives and the direction of movement are usually prescribed (e.g. roller coaster ride). Accordingly, 360° photos are not considered in the following, but moving image content is.

360° videos are often also referred to as VR videos; the term interactive video is also common. However, this requires the viewer not only having the possibility to freely select the perspective and direction of movement, but also the possibility to influence the narrative of the video within an interactive framework. This is possible by means of projected control elements and can, for example, include influencing a plot line and also enable the selection of a scene change.

It is important to emphasize that there are currently no agreed standards for the production of VR videos. 360° videos, which from a technical perspective are relatively easy to realize, are currently spreading via social networks as a new content format.

AR videos also focus on interaction with the content. Here, virtual, graphic components are added to the perceived real world. In addition to scenic applications, interactive AR videos are often used as installation guides and as work support systems.

The way in which 360° as well as VR and AR videos can be consumed and which of the above-mentioned properties of the media forms are accessible depends strongly on the type of output device, that is, the display. Basically, there are two classes of output devices:

- Head-mounted display systems
- Projection-based systems

Video glasses represent the simplest form of a so-called Head Mounted Display (HMD). This consists of a head mount, one or two miniature screens, headphones and usually additional

screens that allow video information to be viewed undisturbed by external optical stimuli. Video glasses are mainly used in the private sector to watch videos from DVDs or TV programs and streams, as well as for computer games (see Figure 4). These are divided into binocular systems (1, 2 and 3 in Figure 4) and monocular systems (4 and 5). HMDs are available as see-through (augmented reality) and non-see-through (virtual reality or 360°) variants (*Federal Institute for Occupational Safety and Health (BAuA), 2016*).

Figure 4: Various Head-mounted Display Systems (HMD)



Source: Federal Institute for Occupational Safety and Health, 2016

VR glasses contain additional sensors to detect the movement of the head, which are important for influencing perspective and/or direction of movement. Input devices are interaction devices such as game controllers, gloves, 3D mice, etc. that are used to interact with the content. Modern, contactless operation by means of gesture recognition via cameras or electromagnetic systems also enables seamless interaction with the displayed content.

In contrast to HMDs such as video glasses and VR glasses, AR glasses project virtual information in front of the user's eyes, while its display is not visually shielded from the outside world. Depending on the type of glasses (monocular or binocular) 2D videos or Internet pages can be displayed (e.g. monocular Google Glasses) or 3D graphics can be projected into the field of view (e.g. binocular Microsoft HoloLens).

As an alternative to the head-mounted variants of AR and VR, there are also projection-based variants. Currently, most common and also simplest form are the 3D-stereoscopic cinema films, which however are not VR applications in the literal sense due to the lack of interaction options. Projection-based systems include the so-called CAVEs (Cave Automatic Virtual Environment) as rear projection-based VR displays. CAVEs are mainly used in research and for 3D prototyping in the automotive, aerospace and robotics industries. The illustrations in *Figure 5* and *Figure 6* give an impression of the possibilities and size of the projections.

Figure 5: CAVE as Rear Projection-based Virtual Reality Display



https://upload.wikimedia.org/wikipedia/commons/1/1e/Roboterbasierter_Flugsimulator_Grenzebach_FlightSim.jpg

Figure 6: Projection-based Augmented Reality Solutions



Source: Own research from the BMBF Project: "Development of an augmented reality system for intraoperative navigation using the example of individual graft design in oral and maxillofacial surgery".

2.2. Industrial Economic Structure of the Sector

The VR/MR/AR sector describes a comprehensive ecosystem with numerous overlaps between the individual sub-sectors. For a more detailed analysis, a grid will first be developed to structure the activities more precisely. In this context, it is advisable to group the companies according to their position within the value creation chain. In addition, market-related target industries and the content/functionalities offered can then be defined.

2.2.1. Breakdown Based on the Value Chain

Overall, a distinction must be made between different submarkets for VR, MR and AR, which are each served at different stages of the value chain. In principle, the value chain of media production can be used as the basis for a general description of the sector.

This shows that different emphases can be identified here. Established media players and also large (Internet) corporations are trying to penetrate the market and thereby achieve greater vertical integration. The example of the consumer VR segment (see Figure 7) shows, for example, that social networks and data-driven online players are trying to largely occupy the value chain, whereas traditional media companies tend to limit their activities to aggregation and production.

Figure 7: Integration of Value Creation Stages in the B2C VR Market

	Content producers	Aggregations	Infrastructure providers	Device manufacturers	CE retail
TV stations	✓	✓			
Publishing companies	✓	✓			
Game developers	✓	✓		✓	
Social networks	✓	✓		✓	✓
Data-driven online/media players	✓	✓		✓	✓
TC network operators		✓	✓		✓
Hardware manufacturers		✓		✓	✓
Retailers		✓			✓

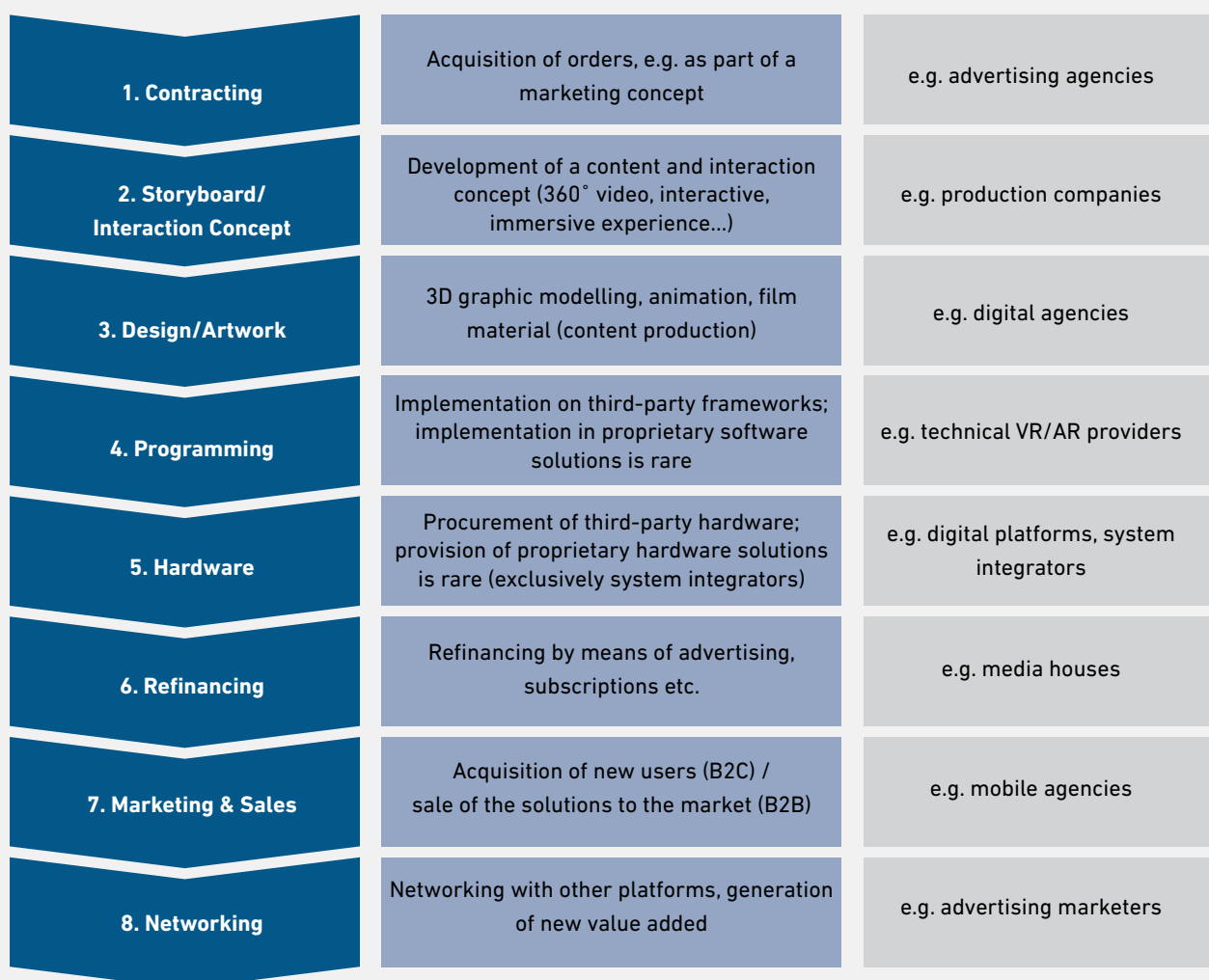
Source: BITKOM, 2016

BITKOM and Deloitte expect that “the ‘winner takes all’ principle that dominates the Internet world and the associated oligopoly formation (...) will presumably also be continued in the field of virtual reality” (BITKOM, 2016). Here, large players active at several stages of the value chain have the advantage of occupying the market. With a view to the North Rhine-Westphalian VR/MR/AR sector, none of these globally active companies are currently based locally.

However, in the B2B market, there are players who play a similar role – albeit much more specifically – and who themselves cover various stages of the value chain. However, this is the exception rather than the rule.

The majority of the companies surveyed are active in the first two stages of the value chain. Therefore, the value chain for this sector is broken down once again. This is based on a more project-oriented perspective that covers the entire acquisition/production process (see also the example of product development *Berg & Vance, 2017: 11*).

Figure 8: Value Creation Chains for VR-AR Projects



Source: Own research

By the time a contract is signed, an understanding of which issue requires a solution and the customer's value chain will typically have been established already. This basis is then used

to develop the storyboard, whereby a particular focus is placed on the interaction concept. Prominently included in this step will be a specification of how immersive and interactive the experience should be. In particular, this will include a definition of the forms in which the VR/MR/AR application will be offered. Implicitly, this 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 (especially as there is currently a lack of overarching standards (cf. Chapter 3.3.3.)).

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 some forms of VR/MR/AR applications tend to be designed for the no-cost market, 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.

2.2.2. Breakdown by Markets

Relevant literature currently distinguishes a number of core sectors in which virtual, mixed and augmented reality content is used. For the sake of clarity, manufacturing industries are grouped as one sector, although it encompasses a number of different sub-sectors (e.g. automotive, aviation).

The individual sectors crop up to differing degrees in content offerings or application scenarios that can be implemented beneficially using virtual, mixed and augmented reality. 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:

- **Education/Information:** 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.

- **Entertainment:** This area encompasses the plethora of showcases, especially sporting events, in which widespread interest, personal investment and a willingness to pay are most likely to coincide. Other application areas include concerts/music, although users have not yet demonstrated a sufficient willingness to pay, despite the considerable success of individual productions (EDFVR, 2017: 26). **Gaming** content is currently among the 'killer applications' in this field. Sophisticated VR games for consoles and smartphone-based applications are both becoming increasingly popular, as evidenced by Pokémon Go.

Figure 9: Target Market Content Matrix for Virtual and Augmented Reality

	Gaming	Medicine	Arts/architecture	Media	Advertising/marketing	Manufacturing industry	Tourism	Logistics	Live entertainment	Military
B2C		✓	✓	✓	✓		✓			✓
	✓		✓	✓	✓					
B2B			✓	✓		✓	✓	✓		✓
	✓		✓	✓	✓		✓			
		✓				✓				✓
		✓				✓			✓	✓
		✓	✓			✓				✓
		✓				✓		✓		✓

Source: Own research

- **Assistance 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.). Logis-

tics companies are also active in the B2B segment, alongside companies that are keen to optimize their internal warehousing/picking and to manage their flow of goods. For instance, DHL was able to cut the time required for picking by 25% in a pilot project in the Netherlands (*Roth, Zanker, Martinetz, & Schnalzer, 2015: 21*).

- Another hybrid use case that is of equal interest to consumers and business customers alike is the **design of product presentations, i.e. 'experiences'**. Numerous use cases currently exist on 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 stand. While these use cases are naturally crucial in the areas of marketing & promotion, they are vital to providers in the fields of arts & architecture as well.
- In the area of **education & training**, VR, MR and AR applications allow course participants to complete simulations or to obtain additional information on specific subject matter. There is a particular need for this kind of application in the industrial sector, but also within medicine and the armed forces, as upstream simulation of such complex and potentially critical live situations offers significant advantages.
- Applications in the areas of **maintenance/service/production** follow the same logical principles: They are mainly concerned with using augmented reality as a means of optimizing workflows. Studies conducted in the aviation sector indicate that searching for printed documents accounts for around 40% of the time expended on maintenance (*Kluge, 2009*). In particular, a greater focus on information-assisted processing enables standardization of workflows that in turn ensures more collaborative completion – with all the associated optimization potential (*Roth et al., 2015: 30*).
- **Design and prototype manufacturing** is a specific category within the production process. Industrial enterprises and the scientific community can benefit significantly from this application. 'Artistic' applications would be conceivable as well.
- Finally, VR and MR applications in particular enable improved collaboration through **virtual conferences** and data visualization, etc.

An overview by Deloitte indicates that different types of devices can be used in the various scenarios (*cf. Figure 10*).

Figure 10: Suitability of AR/MR/VR Types for Use Cases

	Low-end VR	Mobile VR	Full feature VR	Smart glasses	NextGen AR/MR
Marketing, promotion	✓	✓	✓		✓
Product presentation, virtual showrooms & visualization	✓	✓	✓	✓	✓
Seminars, training & simulation		✓	✓	✓	✓
Design & product development			✓		✓
Conferencing & collaboration		✓	✓		✓
Maintenance & repairs				✓	✓
Logistics & navigation				✓	✓
Production				✓	✓

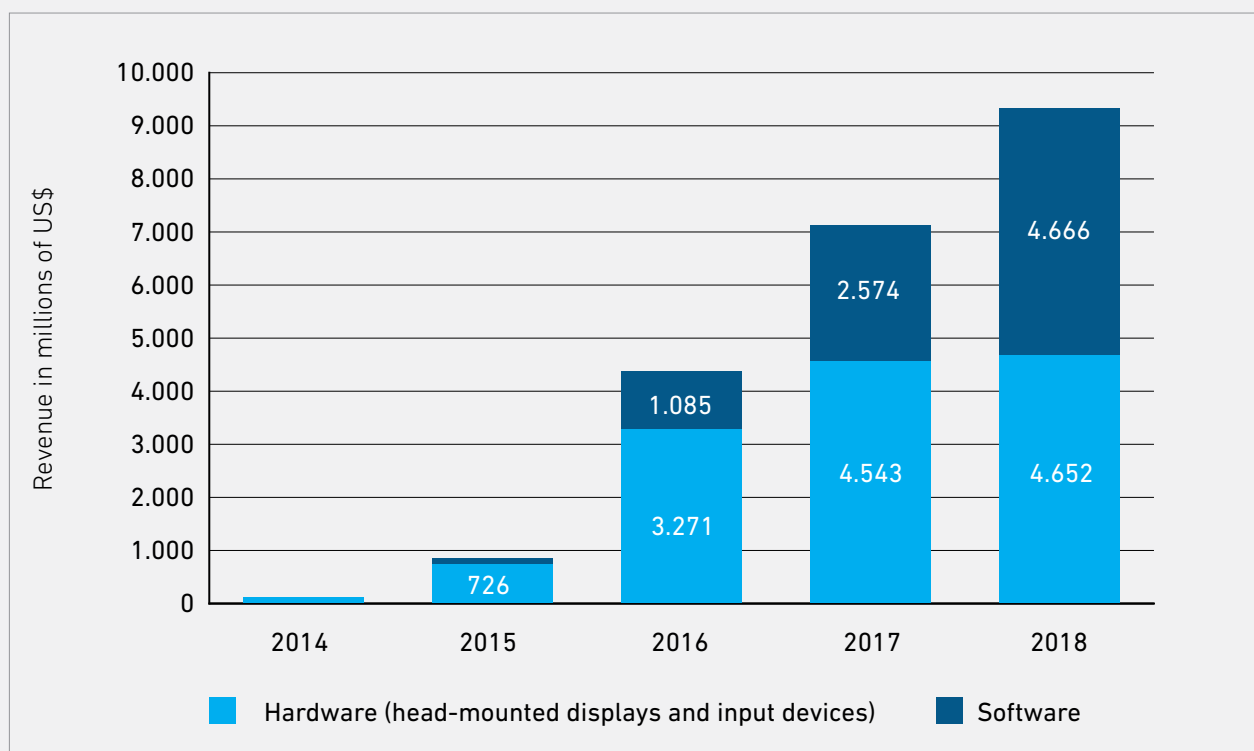
Source: Deloitte, 2016

3. THE MARKET FOR AUGMENTED, VIRTUAL AND MIXED REALITY IN GERMANY

3.1. Sales Performance in Germany

Overall, market observers predict significant growth in the segments of virtual, mixed and augmented reality. Among them is PricewaterhouseCoopers, which assumes that sales of VR offerings will rise sharply in the coming years from US\$726 million in 2015 to more than US\$9 billion in 2018. While sales of hardware dominate at the moment, it appears likely that software and hardware will make equal contributions to sales in this field in the future (cf. Figure 11).

Figure 11: Worldwide VR Sales, 2014-2018



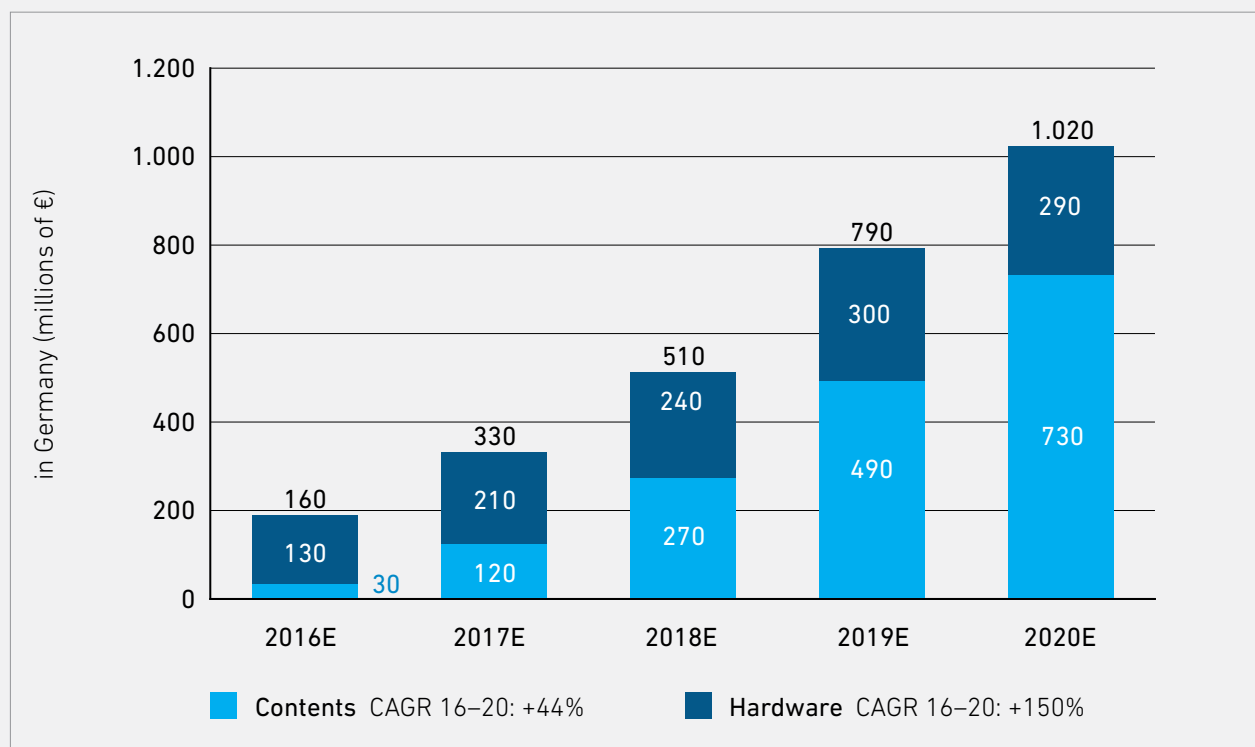
Source: PricewaterhouseCoopers, 2016b

More optimistic figures are released by Digi Capital, which identifies combined sales of US\$3.9 billion in 2016 (comprising US\$1.2 billion for AR and US\$2.7 billion for VR). However, the consultancy organization estimates that in the medium term, AR will account for sales of US\$83 billion and will hence become a much larger market than VR (US\$25 billion) (Digi Capital, 2017).

Nevertheless, it is worth noting that the consultants' predictions have remained unfulfilled so far. They suggested that around seven million Samsung Gear VR devices would be shipped to customers in 2017, ahead of Google Daydream (almost four million) and PlayStation VR (a good two million systems). But sales are lagging significantly behind the forecasts. Super-Data Research predicted that global sales would reach around US\$5.1 billion at the beginning of 2016. In the end, the actual figure was just US\$1.8 billion (*The Economist, 2017*). This indicates that the predictions released by Deloitte and PricewaterhouseCoopers are already far too optimistic.

Overall, the frenetic growth should be reflected on the domestic market as well. The consultancy firm Deloitte predicted that the German market would reach a volume of over €1 billion in 2020 (*cf. Figure 12*). In producing this number, Deloitte assumes that growth will be particularly strong in the content segment. Sales (largely for computer games) in 2020 will reportedly exceed the currently dominant hardware revenues by far.

Figure 12: Virtual Reality Sales in Germany, 2016-2020



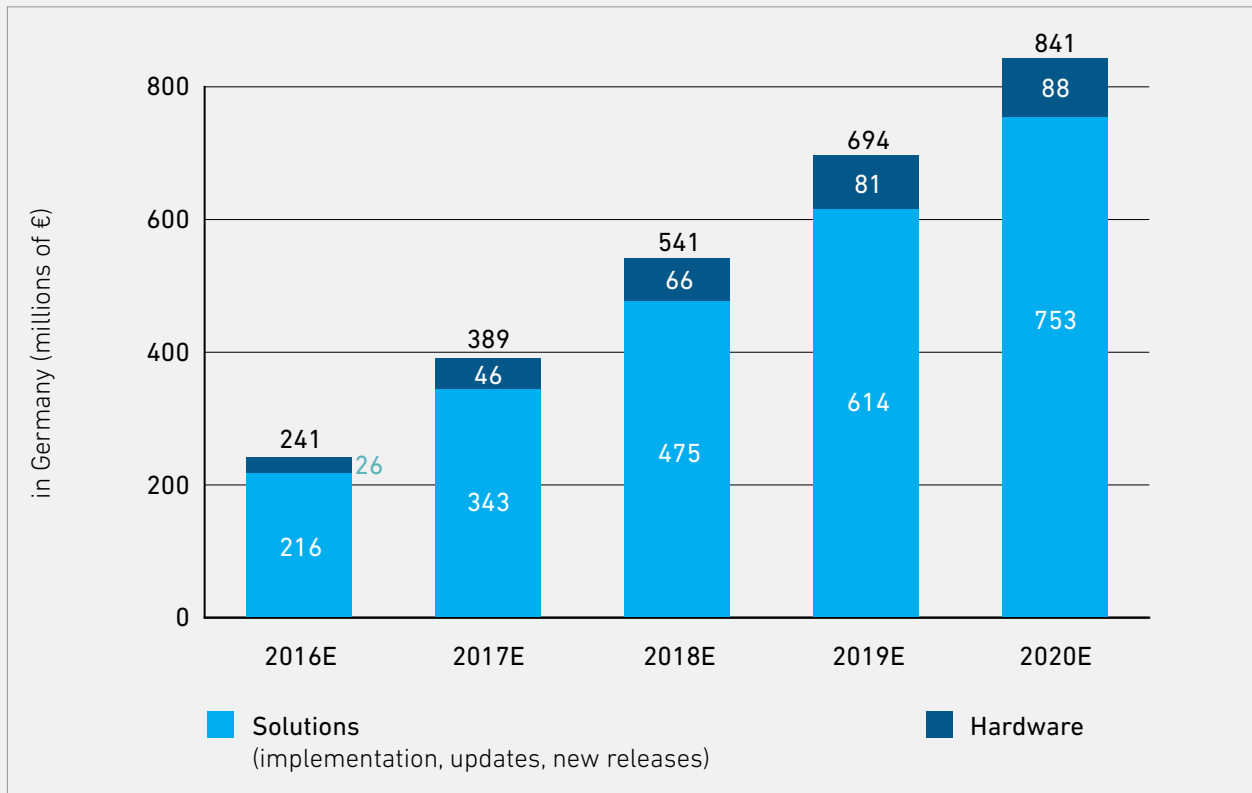
Source: BITKOM, 2016

Basing its figures on a study by Juniper, Deutsche Bank estimated that the market for augmented reality would grow to US\$500 million in late 2015 and that sales would then rise to US\$7.5 billion by 2020. Here, western Europe would account for €1.7 billion and North America for just under €3 billion. In total, the number of users around the world will reportedly rise from 60 million in 2014 to 350 million in 2020 (*Heng, Hörster, & Karollus, 2015*).

Prospectively, a division of the market into 'purpose-built' and smartphone-based device categories will be observable. This is highlighted in a study by the Japanese consultancy firm Techno Systems Research, which claims that just over three million head-mounted displays will be shipped for each of the VR, MR and AR categories (for non-smartphone applications) in 2020 (*Techno Systems Research, 2017*). Several hundred million smartphones with AR and VR capabilities should also be expected.

Another division of the market into the B2B and B2C segments is distinguishable as well. Deloitte anticipates strong growth on the B2B market, where German companies are expected to invest €840 million in the market for VR, MR and AR as early as 2020 (*cf. Figure 13*). This market differs significantly from the consumer segment, where hardware accounts for the lion's share of sales. In contrast, Deloitte estimates that 90% of current sales in the B2B segment relate to the "development, licensing and maintenance of specific enterprise solutions". Growth is expected in the areas of full feature VR headsets and smart glasses especially, whereas low end and smartphone-based models will largely be found on the B2C market (*Deloitte, 2016*).

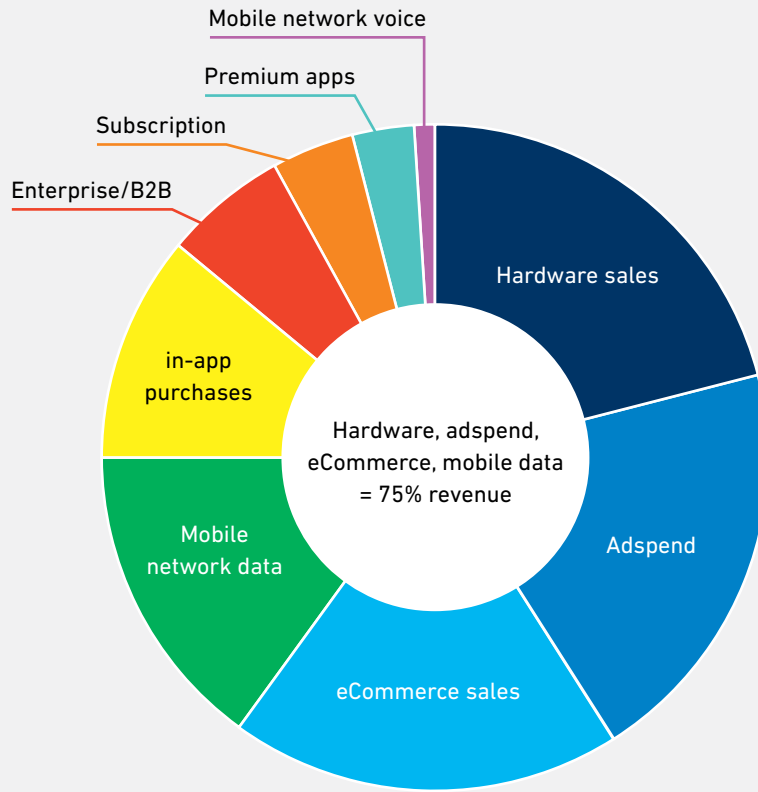
Figure 13: Development of B2B Sales in Germany, 2016-2020



Source: Deloitte, 2016: 11

It is currently impossible to predict with any degree of precision how value added will develop in this segment in the long term, as the markets are still in their infancy. Notwithstanding, most studies assume that software will become the dominant force, while hardware investments will likely be restricted to replacement purchases once the market has matured in the medium term. Digi Capital's overview of the long-term business models in the areas of VR and AR illustrates this trend (cf. Figure 14).

Figure 14: Long-term Business Models in the VR/MR/AR Market



Source: Digi Capital, 2017

3.2. Use of VR, MR and AR in Germany

There are currently no measurements or statistics available that comprehensively describe the use of VR, MR and AR applications. In most cases, not even device sales are broken down to the level of the German market. It is therefore necessary to draw on individual surveys of issues that are suitable for estimating the intensity of use to a limited extent only.

In June 2016, PricewaterhouseCoopers conducted a representative survey of the use of VR offerings in German society. At the time 84.3% of respondents were familiar with the term, but had not used any of the applications, while 15.7% reported personal experience with VR (*PricewaterhouseCoopers, 2016b*). Gaming was the most frequent use case: 19.9% of the surveyed gamers (respondents who play computer games at least once per month) had already acquired experience with VR. But only 3% of the respondents stated that they owned a VR headset. Use itself remained irregular as well: 71% of the VR users stated that they use VR only occasionally (less than once per week).

Only 21% of the respondents stated a current interest in purchasing a headset. The indifference price (equal numbers of respondents stating that the price is too high or too low) in the study was just €87.00, so significantly below the manufacturers' asking prices. Willingness to invest centered mainly around the availability of suitable computer games (36.7% of the respondents). Treadmills, 3D mice and similar accounted for around 20%, respectively. Overall, the respondents expect the prices to drop further and the technology to become increasingly mature. Use cases are seen predominantly in the industrial sector (*PricewaterhouseCoopers, 2016b*).

The situation on the AR market is similar: 74% of the respondents in 2016 stated that they had heard the term (*PricewaterhouseCoopers, 2016a*). The same figure in 2015 was just 22% of 18 to 35-year-olds (*Heng et al., 2015*). 48% of the respondents aged 30 and below had already used an AR application, which represents a rapid change, also driven by the hype surrounding the AR game Pokémon Go. Among the AR users, gaming applications (34%) were the dominant factor, ahead of navigation applications (20%) and online shopping (18%). This was followed by trade show presentations and assistance systems for interior design (13.5% and 12.5% respectively). Events/permanent installations is another use case. In 2016, the Spirit research project by RheinMain University of Applied Sciences studied 111 relevant apps and came to the conclusion that only 13% of use cases currently include augmented reality content, which is refinanced indirectly in each case by means of sponsoring, advertising or own resources. Permanent installations in particular generate value added, for instance in

amusement parks, zoos or museums, as elaborate storytelling is worth the investment in these areas (*RheinMain University of Applied Sciences, 2016*).

3.3. Opportunities and Challenges of the VR/MR/AR Sector

The following will investigate the opportunities and challenges facing the VR and AR sector. Analysis is based firstly on the expert interviews and secondly on the interpretation of the survey, which are combined with the insight acquired from desk research in a third stage.

Overall, the respondents and the vast majority of studies assume that virtual reality applications will possess greater market relevance in the short term – also because augmented reality is still in an extremely early phase of its market introduction. The observations in the following sections will therefore place a greater focus on the market for virtual reality. However, trends that feature the emergence of mixed reality applications will also be considered commensurately.

In this regard, respondents expect that smartphone-based augmented reality applications in particular will account for the larger market in the long term. Although professional and personal use cases can be inferred for both technological approaches, the majority of respondents presumed that VR will mainly possess business significance (e.g. optimization of the value chain, marketing, collaboration), while augmented reality is likely to be more consumer-oriented (e.g. entertainment, information).

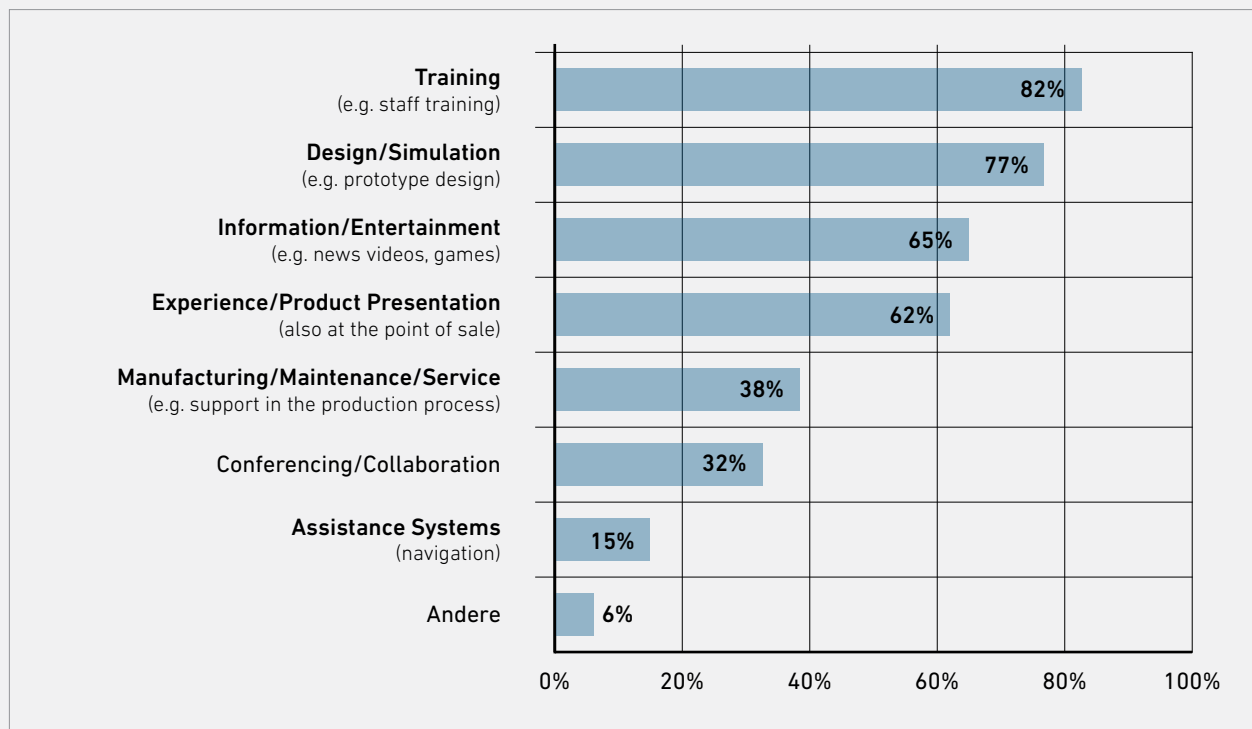
3.3.1. Possible Use Cases for VR

Overall, VR is perceived as an area in which expectations outstrip its current business potential by far – in this context, several interviewees spoke of a “hype” that might ultimately become harmful if the expectations remain unfulfilled (cf. Chapter 5.3.). While some providers – in this case more established players – successfully market applications for industrial partners (for example), many younger companies are still searching for ways to generate substantial sales.

In this context, the surveyed companies have a fairly clear idea of which kinds of application will be particularly auspicious in the coming 18 months. First among them are training apps, followed by others that can be used for simulation and prototype engineering/design.

Information and entertainment offerings, as well as product presentations and experiences, are also perceived as particularly attractive (*cf. Figure 15*).

Figure 15:
Assessment of the Attractiveness of VR Use Cases in the Next 18 Months



Source: Online survey, n = 34; multiple answers possible

The expert interviews lend credence to these findings. Many uses cases that are currently being commercialized are designed for marketing purposes or for communication with consumers (*EDFVR e.V.e 2017: 34*):

- On the one hand, this includes presentation of new products in the automotive industry and elsewhere. 18 of the top 20 vehicle manufacturers in Germany have their own sales-oriented VR or AR application; seven have an after-sales offering and 17 even have in-vehicle apps. Some of them have a remarkable reach: Of the 57 applications that automakers have released for the Android platform, 5 have been downloaded more than 50,000 times (*Hauck & Pagel, 2017a*)
- Presentation at the point of sale is another major field. Experts believe that a com-

bined online/offline presence is especially advantageous here. This would resolve the distribution problem relating to VR and AR in particular, as the customers would already be in the retail outlet and could use the individual offerings directly. Faced with the insufficiently widespread use, customer acquisition is believed to be crucial. Moreover, it is expected that applications for domestic use that accommodate all facets of interior design will be offered. This trend is already evident in the area of home viewings or the design of new builds – two areas for which numerous VR and AR applications have already been developed, albeit with comparatively modest success (*Hauck & Pagel, 2017b*). It is also believed that fashion labels in particular will develop use cases, although all store design showcases will still have to demonstrate how they offer additional benefits compared to more conventional software (interview with M. Dierking/Virtalis, 2017).

- Practical use cases in the area of wayfinding/navigation are also widespread, for instance in the banking industry, (*Hauck & Pagel, 2017b*), although the quantitative success of these applications has remained quite moderate so far.
- Experts believe that events/trade shows can also be a special use case. Given that VR primarily remains an accompanied experience – even experienced users often require instruction – event formats in which personnel are on site to explain how to operate the equipment offer particular potential. VR arcades are believed to be attractive in this regard, whereby more sophisticated applications are likely to dominate this area in the longer term (e.g. The Void “Star Wars Experience”, cf. *Chapter 4*).

Finally, the findings of the survey indicate that the entire information/entertainment segment is considered highly attractive. The gaming industry takes the lead in this field – it is widely seen as the key application form with relevance to consumers, both in regard to the installed device sets, as well as the number and relative sophistication of offerings and their use. In addition, experts mention the production of moving image content as a key area, whereby the focus is on the development of dedicated interactive applications, especially 360° videos. Within the field of 360° videos, experience acquired so far indicates that informational content will be especially promising, as the level of immersion for VR users is particularly high. By and large, the respondents expect that VR content will be produced as an addition to linear production content, instead of as elaborate ‘standalone’ items. Sports and music events are also promising areas for the production of moving images. In Germany, for instance, Sky already offers innovative formats via its own VR production company that allow users to ‘sit’ ringside at boxing events or experience motor races from the track. Figures released by the

company indicate that more than 100,000 customers already use these options (*EDFVR, 2017: 16*). Deutsche Telekom AG has implemented a similar use case as well (*cf. Chapter 4*). Questions of how to translate narrative storytelling into live situations will also become pertinent with the anticipated establishment of live productions. The necessary technology might even be sufficiently mature within the next 18 months.

In addition to consumer-side applications, others that are designed specifically for business customers or are integrated within production processes are also believed to be attractive. International surveys indicate that VR is already used in a variety of value chain processes across a range of industries, from product design to production support (*Berg & Vance, 2017*).

- Most experts concurred that significant potential is likely within education and further training especially. Of particular interest in this regard are situations that are difficult to simulate, for instance medical surgery or fire drills. But VR can also be beneficial to 'run error scenarios' in less critical situations, making the technology suitable for use in training professions within the trades sector. The operation/configuration of expensive devices and major systems (e.g. turbine assembly) or work in difficult environments (e.g. nuclear power plants) are also easy to simulate. Also included within this field is the communication of knowledge to geographically distributed employees, for example to give sales assistants in the field a first-hand experience of products that require explanation. VR is seen as a particularly suitable technology to impart knowledge, as it creates a very concentrated learning environment that is largely undisturbed by environmental influences.
- Product design is regarded as a second important field, as indicated in the survey as well. This applies to prototype visualization in manufacturing industries, e.g. in the automotive industry, as well as to pre-visualization of retail space or outlets before they are built (*Berg & Vance, 2017; Hauck & Pagel, 2017a*).
- The experts also believe that the consultative integration of cases – an area in which numerous digital agencies are already operating – presents another business field. In this area, the hope is to progress beyond isolated showcases and to accompany change in the value chain processes, possibly through the use of a dedicated platform. Nevertheless, individual concepts for diverse application forms continue to dominate.

- Finally, one category of applications is designed to improve communication and workflow management in a corporate context. This includes VR conference rooms and systems to enable collaborative work, to which individual respondents attribute considerable potential.

Additional use cases are expected in all of these fields, especially as technological progress continues. In this regard, the experts believe that dismantling the obstacles to use will be crucial in order to enable integration within routine tasks. Application mobility (e.g. in the form of smartphone-based applications) is seen as an important development, alongside immersive desktop PCs. Moreover, VR might also be suitable for coupling with artificial intelligence, as it always operates in a virtual – and hence easily controllable – environment. The visualization of large datasets and the design of interaction with artificial intelligence are among the challenges in this regard (*interview with T. Kuhlen/RWTH, 2017*).

Experts also believe that the technologies will enable greater immersion, e.g. by permitting greater freedom of movement, tactile feedback or even holographic imaging and volumetric videos. Ultimately, the goal is to model reality as perfectly as possible. However, this would create higher demand for narrative user guidance (see below). Contrasted with this are concepts (especially in a professional context) that are not designed to achieve immersion and instead replicate the key characteristics of a particular situation in a pared-down form in order to allow focused experience, work or learning.

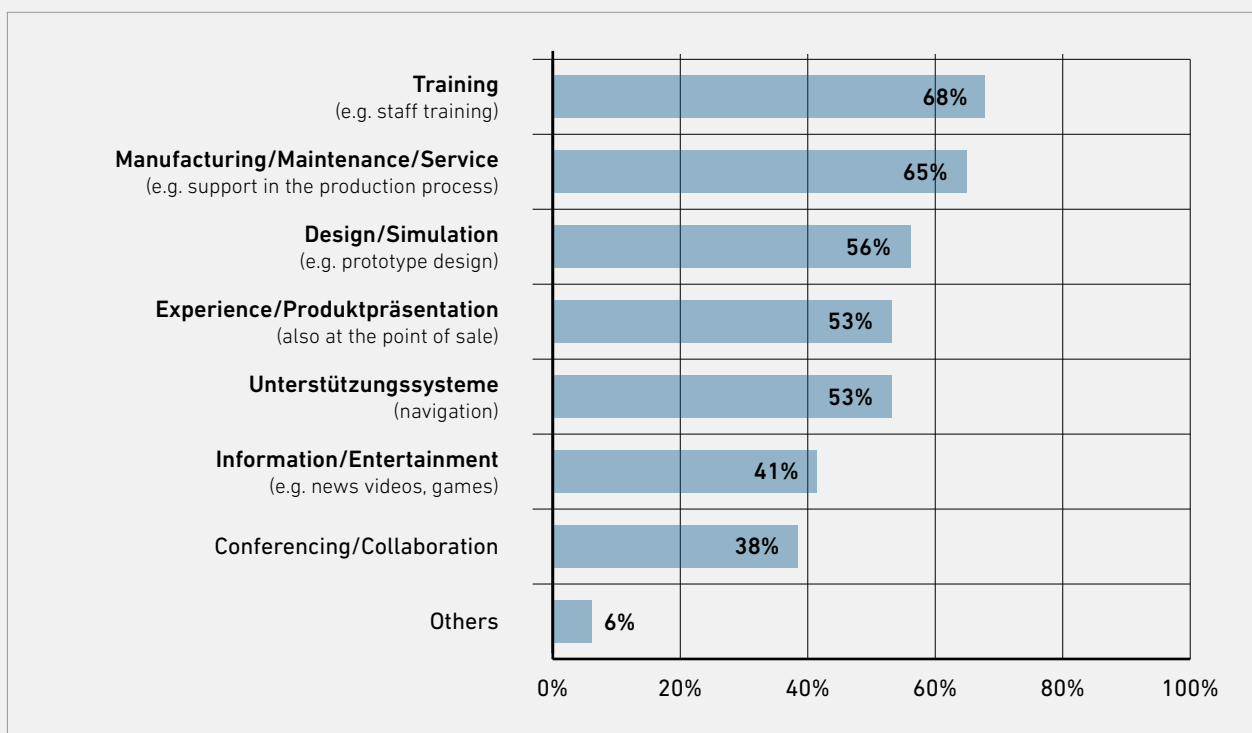
3.3.2. Possible Use Cases for AR and MR

According to the respondents, augmented reality is believed to be less advanced than VR at present. Despite there being a few successful applications, e.g. Snapchat Lenses, AR is currently believed to be “progressing toward” (*interview with F. Heineberg/CBC, 2017*) more widespread adoption by the market. Significant hopes are placed in the announced (or recently released) software developer kits for Android and in particular the Apple platform. The hope is to change the common perception of AR as an ‘application for teenagers’. At the moment, there are fewer implementations than in the VR segment, especially if the gaming segment is left out. Therefore, the study will consider MR applications together with AR from this point forward.

The companies surveyed believe that the main use cases for AR and MR will be in training and education, as well as in manufacturing, maintenance and service. Secondly, they consider product presentation/experiences and design/simulation and navigation systems

to be particularly promising. This reveals striking differences to the assessment of the VR segment, which is believed to have insignificant potential in the areas of manufacturing/maintenance and navigation.

Figure 16:
Assessment of the Attractiveness of AR and MR Use Cases in the Next 18 Months



Source: Online survey, n = 34

The survey shows that considerable hopes are placed in AR and MR applications within the B2B environment, as they can be integrated seamlessly into company workflows. Scenarios focus on the visualization of additional information (e.g. for medical-technical assistants or in the training of technicians). There are additional opportunities in logistics and other fields, e.g. for navigation within buildings (*Federal Institute for Occupational Safety and Health, 2016*), or workforce collaboration (whereby the design of non-intrusive applications for employees that do not have access to AR or MR hardware and others is seen as particularly important). Nevertheless, industry figures indicate that it would still be inaccurate to speak of widespread utilization, even for more 'major' use cases – in almost all cases, only individual devices are

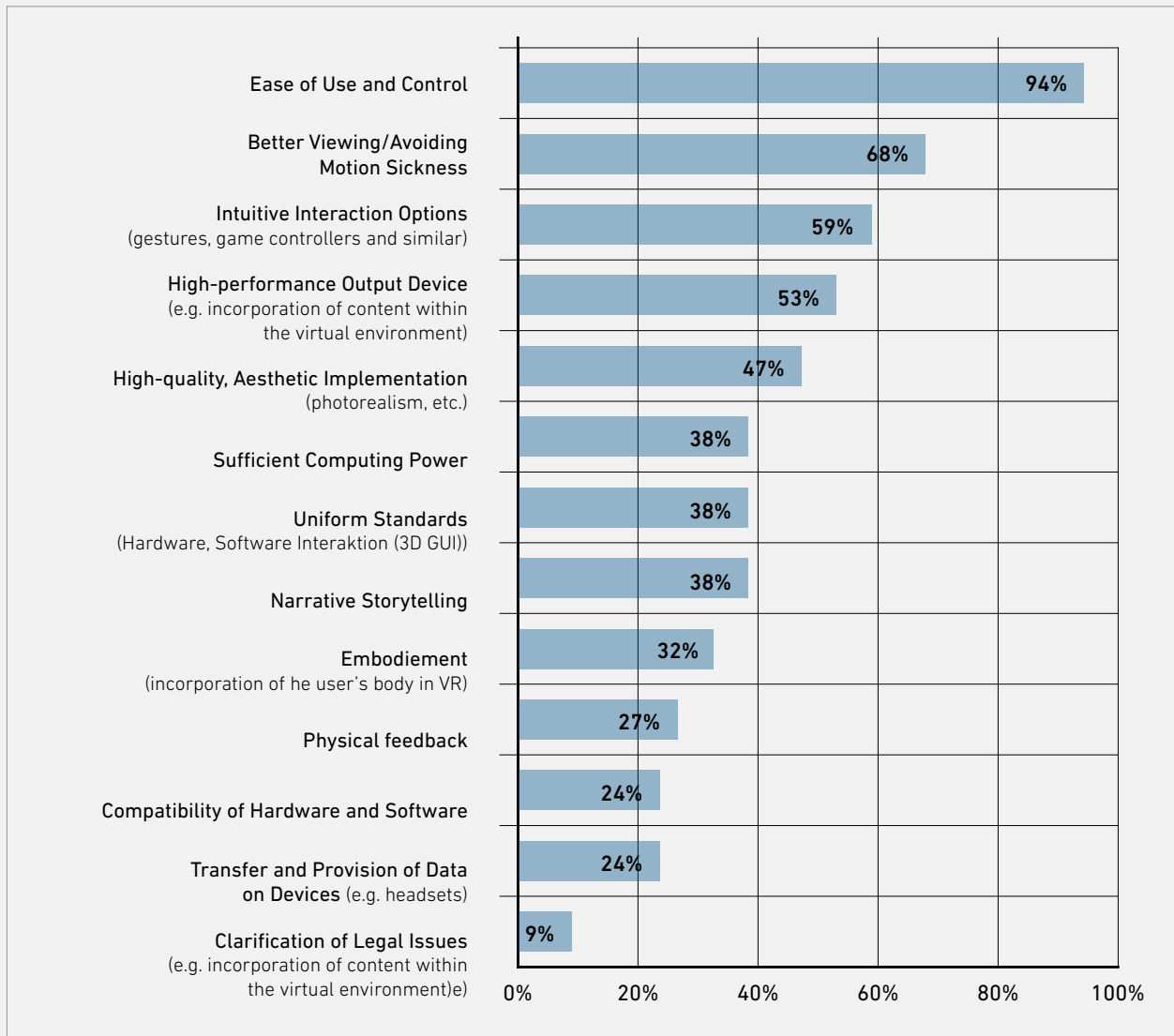
used, making it more appropriate to speak of showcases. One of the reasons for this is the significant price of MR output devices and their inadequate quality, which is largely attributed to the small field of vision (*cf. Chapter 3.3.4.*). This situation might change with the release of new devices. Integration of data visualization is seen as another problematic area.

Although, as we have seen, AR and MR applications remain rather thin on the ground, AR users still believe that the technology offers substantial potential, especially in the segments of medicine (e.g. surgical assistance systems), interior design, gaming, tourism and education. A survey conducted by PricewaterhouseCoopers indicates that around 40% of respondents that had used AR in these categories believe it has a promising future. This is followed – at some distance – by concepts for retail (26%) and applications within the production process (e.g. planning, maintenance and service, *PricewaterhouseCoopers, 2016a*).

3.3.3. Challenges for the Adoption of VR

Companies in NRW believe there are several groups of issues that are obstructing development within the VR sector. Most important among them is the devices' ease of use and control (94% of the surveyed companies). This is followed by better viewing of the content and the prevention of motion sickness (68%), intuitive interaction opportunities (59%) and high-performance output devices (53%). Moreover, at least a significant minority mentioned a number of other factors that they believe to be crucial (*cf. Figure 17*).

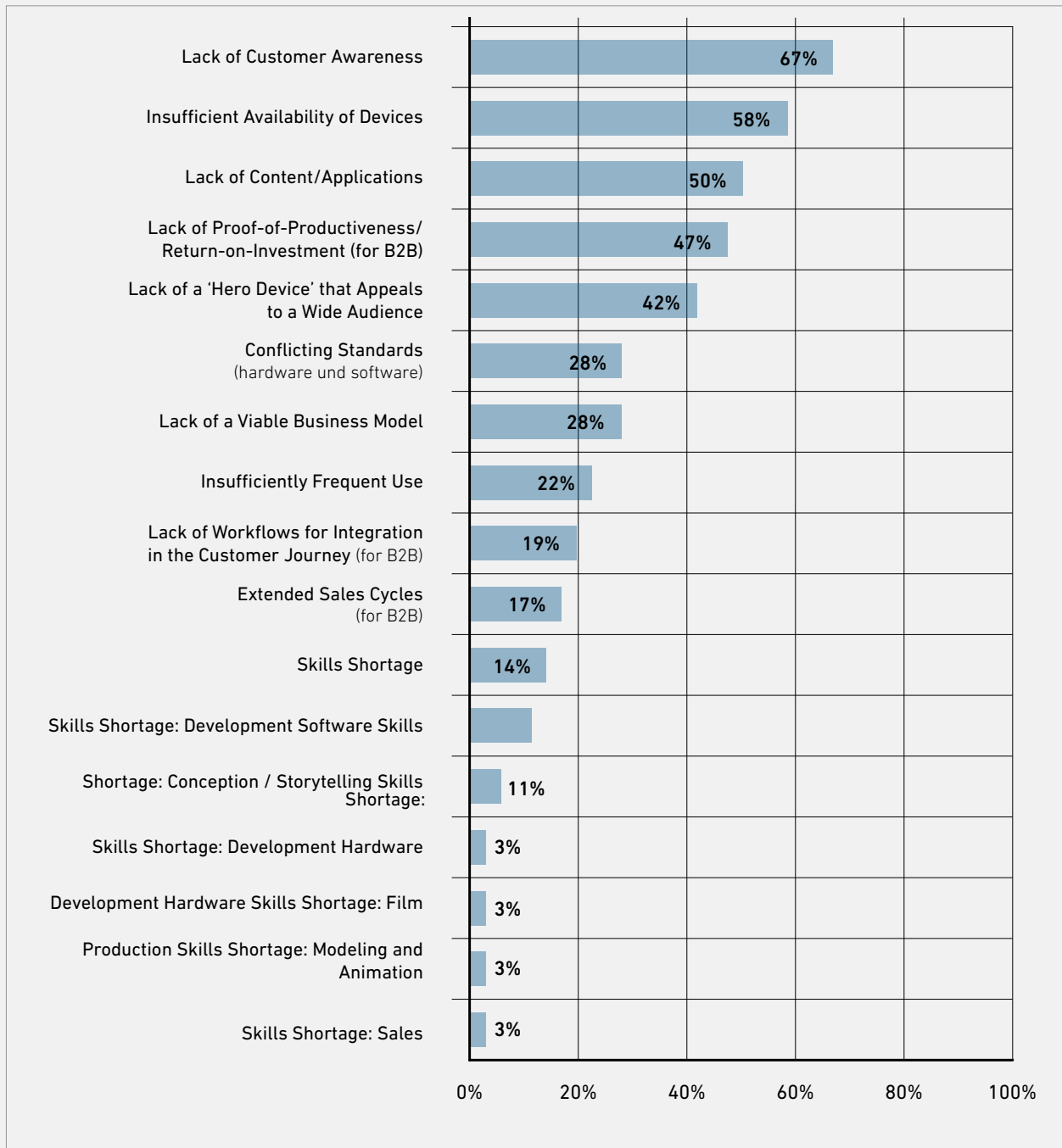
Figure 17: Factors for the Adoption of VR



Source: Online survey, n = 34

Aside from these user-related issues, a number of economic aspects are also considered to be relevant for the implementation and long-term viability of VR. In particular, the obstacles include a lack of (end) customer awareness (67%), insufficiently widespread use of devices (58%), inadequate content/applications (50%) and dissatisfactory proof of the return-on-investment for VR applications (*cf. Figure 18*).

Figure 18: Factors for the Economic Development of VR



Source: Online survey, n = 36

For the sake of clarity, the individual arguments were grouped into four categories and explored in greater detail during the expert interviews. The findings are set out in the following.

3.3.3.1 Devices: Distribution, Use, Usability, Performance

At present, VR devices are insufficiently widespread in the consumer market, which means that the range of business models, e.g. for VR advertising, is often inadequate. Several sets of problems are apparent here:

- Firstly, actual awareness of VR remains low, although many people have already heard of the topic (cf. Chapter 3.2.). Among the reasons for this is the lack of opportunity for a wider circle of users outside the gaming sector to familiarize themselves with VR applications in practical scenarios.
- Actual use is too infrequent as well: VR applications tend to be used quite rarely; weekly or even daily consumption is extremely uncommon, even in the gaming segment. The requirements of VR (e.g. assembly/free space in the living room) also present obstacles. In this regard, also with a view to widespread awareness, some experts believe that the establishment of VR arcades might be a way of catalyzing growth.
- The quality of consumer devices is also perceived as inadequate. Although there has been considerable improvement, the devices are still seen as having poor resolution, as well as being too expensive, heavy or bulky.⁴ While more simple devices like Google Cardboard would address the issues of price and weight, they might ultimately be harmful to the adoption of VR, as they inadequately convey the full potential of the medium.
- Another practical problem is the devices' user-friendliness: Experts are calling for them to become more intuitive. This refers firstly to forms of navigation within the VR worlds, where experiments are ongoing into a variety of options (eye tracking, gesture, voice or controller controls). Secondly, entirely practical problems persist for novice users in particular, which extend from the correct insertion of the smartphones into the HMDs and movements in space with wired VR devices, through to banal issues such as the effect of a HMD on the user's hairstyle. These aspects are compounded by the fact that VR applications frequently still require instructions, which presents yet another obstacle to widespread adoption. Experts believe that the development of output devices (e.g. displays) as alternatives to current HMDs might be a possibility.
- Broadly speaking, though, most of the respondents are hoping for the emergence of an out-

⁴ A minority of the respondents believed that resolution is not a particularly critical aspect, asserting that users would simply overlook a lower pixel density.

standing, significantly improved device in combination with a 'killer' application, which – similar to the iPhone in the mobile communications sector – brings an explosion of growth to the market.

3.3.3.2 Standards and Interoperability

The numerous incompatibilities between the various software and hardware components or platforms were perceived as a second significant obstacle. These incompatibilities extend to the individual components: A point of criticism was firstly that although software development kits (SDKs) are available for advertising and object libraries, they are neither free of bugs nor do they offer the necessary level of detail. Secondly, interaction is designed (e.g. tactile feedback via the finger) in different ways for the various hardware solutions, which means that users must make efforts to adapt to different systems. This may even require new programming if the systems prove to be inadequately compatible (e.g. gesture control using Leap Motion, CAVE/HoloLens and Unreal Engine frameworks). According to the experts, one of the reasons for this lack of standards is the rapid technological development we are currently seeing, accompanied by a significant degree of uncertainty.

They express concern that a 'fragmentation' of the market may occur if more mutually incompatible frameworks and platforms are launched on the market in the coming 18 months, e.g. for WebVR systems that currently only support selected devices. This may significantly limit the user experience – and obstruct widespread adoption on the consumer market – if it means that VR applications require more maintenance and become overly error-prone.

3.3.3.3 Monetization

VR is still in an early phase of entering the consumer market, so there is a lack of established monetization models. They do exist in the B2B segment, albeit largely for customized applications produced on a small scale. Experts anticipate that in future, a greater focus will be placed on ROI-oriented indicators, instead of on the novelty/innovation factor. However, these indicators are hard to measure; indeed, suitable elements – e.g. for content – are completely absent from the consumer segment. For instance, there are currently no standardized workflows or advertising accounting systems that are suitable for integration within VR applications. Indeed, the established revenue model based on the sale of games was even perceived as a

barrier to the development of business models that are financed by means of advertising or alternative sources: Given that games played on Oculus Rift or Vive are cross-subsidized, the providers are not reliant on advertising-based (or other) revenue models – a clear competitive edge over providers offering only VR systems. Deutsche Telekom AG has taken the first step in the right direction with its VR content platform. Grouping of content is a fundamental requirement to ensure greater searchability and therefore monetization of VR content.

3.3.3.4 Conceptual Design

The significant media attractiveness of the issue has encouraged a number of providers who are unable to manage the complexity of the applications to cater to less intricate use cases only. There is concern that a wider audience might perceive the issue as 'overhyped'. Regardless, those driving the development are facing new challenges that refer in particular to control, i.e. storytelling, within VR environments. In addition to input/output design, it is also necessary to control the user's attention and to offer deliberate interaction options; equally, different applications require varying degrees of immersion and interaction. Although experience in this field was acquired at an early stage of the medium's development, the respondents agreed that there are still steep learning curves. A rising demand for narrative storytelling is anticipated, especially when volumetric videos and other technologies produce 'walk-through' films in which the user's positioning and integration within the unfolding events produce fresh opportunities. Experts believe that these meta-competencies will become increasingly crucial in B2B applications as well, for instance to structure the learning experience. A number of VR-specific issues also require clarification, e.g. the perception of one's own body within VR (proprioception), the avoidance of motion sickness through synchronization of movements and images, or the design of physical feedback. VR coasters, which are used in amusement parks, are seen as pioneers of the first use cases; but nonetheless the experts believe that significant research is still necessary.

The projects require long sales cycles as knock-on effects of the VR products that are designed largely as showcase/customized solutions. They often start with introductory workshops that address the fundamentals as a means of introducing the clients to the practical aspects of the issue; only then can the actual sales work begin. The cycles can be extremely protracted in the B2B segment and might even reach 18 months or more for projects with a budget in excess of €100,000 (interview with M. Dierking/Virtalis, 2017). Projects in the B2C market can be expected to last several months as well. For instance, implementation of a VR advertising

campaign can certainly take up to six months (interview with C. Kyrion/VIRE, 2017).

This also applies to the entertainment/media segment. While useful empirical values are now available for the planning and production of 360° videos, more effort needs to be invested to persuade decision-makers of the benefits of VR productions that involve a greater degree of sophistication. Some experts believe that many projects suffer from insufficient budgets. This trend can be observed in the area of serious games and elsewhere.

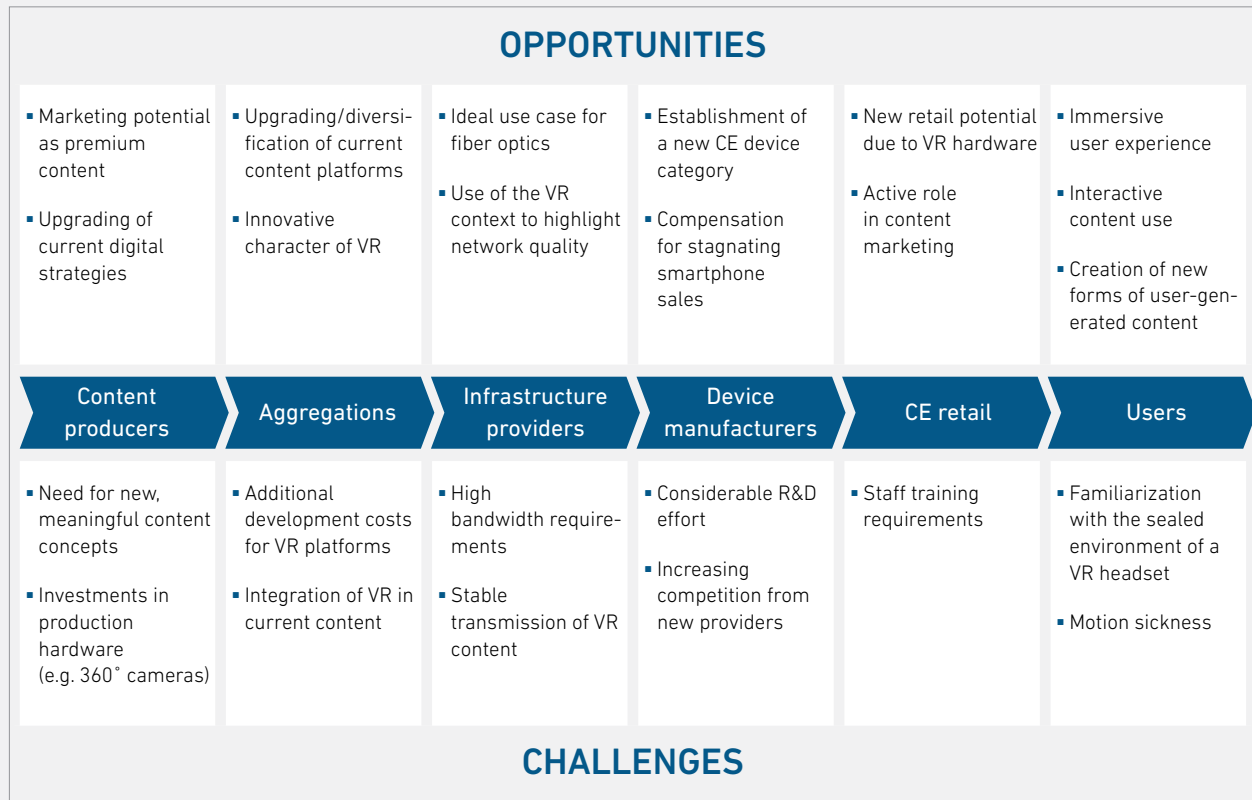
3.3.3.5 Design of the Value Chain

Another important development is the increasing emergence of just a few competing VR ecosystems. Within this framework, devices are integral to the platforms and are combined with purpose-built software and, in certain circumstances, hardware as well (*Heng et al., 2015*). Even providers that offer a complete VR suite as system integrators (in the B2B segment) also use standardized hardware components. While this may certainly create niches in specialized B2B use cases that are not addressed by the major providers, there is a concern that the majority of operators targeting consumers will be dependent on just a few big players.⁵ Nonetheless, the possibility that large platforms like Sony Playstation may open their doors to developers is believed to hold considerable potential, as it might create a significant distribution channel for VR providers. In this regard, it is essential to consider the players that currently operate on the domestic market, but who are not expected to be able to launch a competitive end-to-end solution, for instance Alibaba or Magic Leap.

Each of the stages in the value chain come with differing opportunities and challenges for the adoption of VR. This can be illustrated based on the value chain within the consumer electronics market (*cf. BITKOM, 2016*).

⁵ This presents challenges for public sector providers in particular, as they need to find independent distribution platforms.

Figure 19: VR Along the Consumer Electronics Value Chain

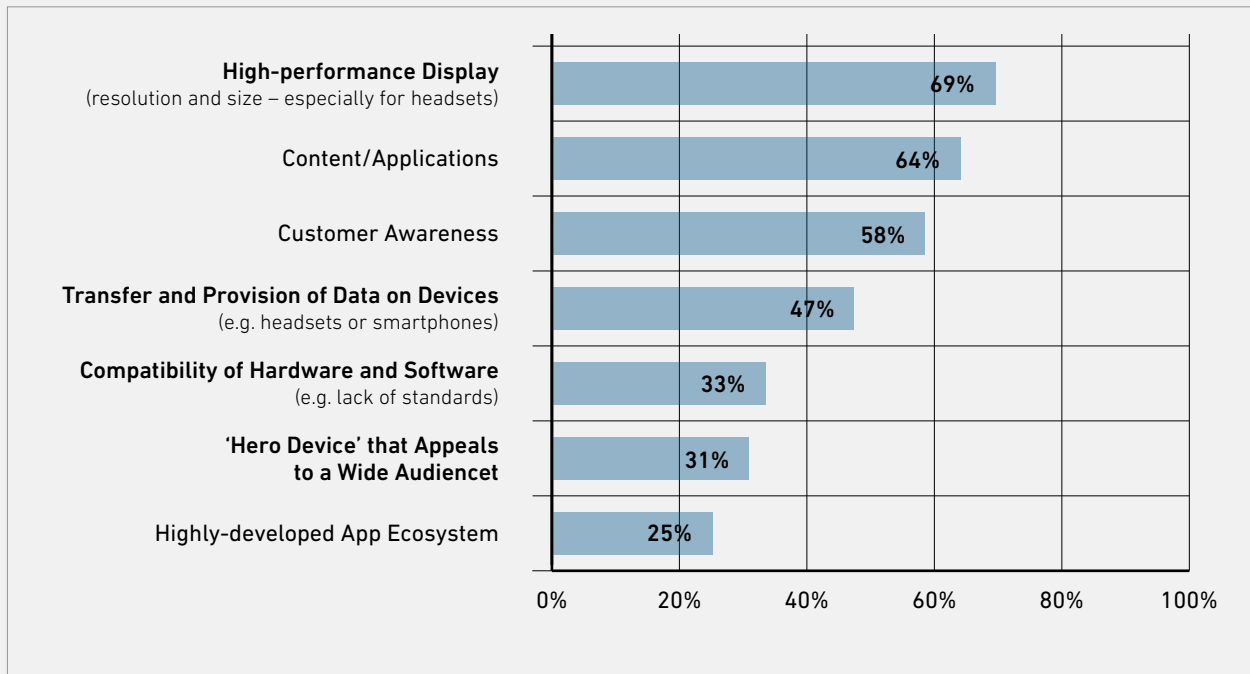


Source: BITKOM, 2016

3.3.4. Challenges for the Adoption of MR and AR

Companies believe that the lack of high-performance devices is the greatest obstacle. Larger displays and better resolution were expected for VR headsets in particular (69%). Lack of content (64%) and inadequate awareness of the solutions among consumers (58%) are also viewed as significant impediments, followed by slow data transmission (47%), compatibility issues (33%), the absence of a 'hero device' (31%) and the need for an ecosystem (25%). Political barriers are also discernable, in addition to these inherent product-related and economic obstacles (Heng et al., 2015). The individual issues are described in the following.

Figure 20: Factors for the Adoption of MR and AR



Source: Online survey, n = 36

3.3.4.1 Technology

From a technical perspective, AR and MR applications are facing similar challenges to VR applications, whereby device mobility in particular represents an additional layer of complexity. Experts and studies agree that sufficient battery life and processing power for displaying the projected information is the first major prerequisite. Moreover, it is necessary to guarantee that the data is transmitted at a sufficient speed. Enabling better viewing of the content is also a sophisticated requirement. In regard to hardware, none of the respondents expressed a belief that the MR devices are sufficiently mature at present: The Microsoft HoloLens technology, which is widely used in this field, is seen as too expensive. The field of vision is also considered to be too small. The possibilities for the display graphics – which are closely associated with performance – are still rated as fairly rudimentary. Consumers also expect greater ease of use and control than is currently available. For instance, it is difficult to explain why – like with QR codes (which are also used infrequently) – a separate app needs to be opened for each use case.

Performance issues are also perceived among MR and AR applications that are designed for

B2B applications in an industrial setting, especially in regard to data provision (fast loading in real-time situations) and data processing (automation of data collection, governance in the merging of datasets, *PricewaterhouseCoopers, 2016a*). While greater output performance (high-quality rendering, high frame rates) is still necessary, for instance in product development, the interaction opportunities in this area are yet another prerequisite (*Berg & Vance, 2017: 13f.*).

3.3.4.2 Regulatory Requirements

Regulatory requirements are cited as the second set of issues. This applies in particular to data privacy. In contrast to highly immersive VR applications, this aspect is of particular importance as AR and MR applications can be embedded in everyday life to a greater extent,⁶ thus increasing the relevance of privacy for users and third parties alike. Another issue is the expansion of network infrastructure called for by the respondents in order to allow for data transmission. The development of suitable pricing models is necessary in this regard, as consumers would otherwise find that their data plans would quickly be used up. In addition, some respondents stated the necessity to enable improved 'metrics' through the assignment of location-based markers and hence to allow function-based tracking and identification of objects for more intensive uses in public spaces.⁷

3.3.4.3 Economic Requirements

While AR and MR applications have already been adopted within industrial settings, they are yet to break through to the consumer market. Experts anticipate that the recently presented AR kits for the major Android and Apple platforms will drive the necessary dissemination. This is a prerequisite for creating an AR ecosystem comprising developers and users that – like in the app stores – produce the necessary variety of applications to encourage larger numbers of users to adopt the technology (*Digi Capital, 2017*).

While Pokémon Go was the 'killer application' on the market for some time at least, no such

⁶ This is because AR applications are dependent on the continuous collection of geodata and other information for the purposes of navigation.

⁷ Added to this are numerous legal issues (which are highly relevant to the concrete use case), for instance the incorporation of real locations and objects within a virtual setting. In this regard, freedom of panorama provisions only allow for the use of images showing the outsides of buildings (*PriceWaterhouseCoopers, 2016a*).

development has been observed among MR applications so far. Use cases that 'only' target a broader audience might be a suitable means of generating attention, thus helping to overcome resistance. It is noteworthy in this regard that many users claim to be familiar with AR or to have heard the term, although actual use remains low (cf. Chapter 3.2.). Among the obstacles to more widespread adoption cited by users are inattentiveness in everyday life (e.g. in road traffic situations (81% of the respondents)), fears that the reality and virtual reality become indistinguishable, as well as dependence on technical devices (56% and 52% of respondents, respectively). There are also concerns about health risks (e.g. nausea, 47%) as well as a general loss of direct experience (45%) (*PriceWaterhouseCoopers, 2016a*).

This low level of penetration is also reflected in the media segment. For instance, neither WDR, RTL, UFA nor ZDF have definite plans to introduce AR and MR media content for consumers. Use cases have progressed much further in the B2B context. In this regard, the AR and MR concepts focus mainly on shortening the time to market for new products. The technology's suitability for individual use cases also needs to be assessed, as 'old-school' methods might actually be more effective (cf. *Federal Institute for Occupational Safety and Health, 2016*).

4. NATIONAL AND INTERNATIONAL BEST PRACTICES

The following section will outline prominent national and international best practice productions from the field of VR/MR/AR that are primarily characterized by coherent and innovative implementation in the interests of users.

4.1. Selected VR Cases

4.1.1. Better than Life / Deutsche Telekom AG

This production, which received the UX Design Award at IFA 2017, allows viewers to transform live broadcasts of basketball games into immersive 360° experiences. Users are transported into the thick of the action and can experience the game from an individual perspective. For instance, they can take part in the timeout with the team, check statistics and even the players' pulses in the live information section or purchase merchandise from the interactive shop. Social media integration allows viewers to share their experience of the game with friends.

4.1.2. My Brother's Keeper / PBS

This VR film production recounts the turbulent relationship between two brothers during the American Civil War. The 11-minute film was shown as part of the VR series at the Sundance Festival in 2017. Aside from the dramaturgical requirements, a number of innovative production techniques were also developed, among them VR slow motion filming with 120 images per second and the development of a specially adapted action camera frame.

4.1.3. Opel "Adam" – Germany's Next Top Model

The OMSTUDIOS Berlin case gives users a 360° experience of a photo shoot with Carina, a candidate in the TV show Germany's Next Top Model. The shoot is part of the music video to "The way she walks" by Whistle Back & Linguistics. The car model Adam features in the background to the video; a giveaway was organized as part of the campaign.

4.1.4. MIYUBI / Felix & Paul Studios

By its own admission, this was the first extended VR comedy (runtime: 40 minutes), it was premiered at the Sundance Film Festival in 2017 and shown as part of the Next program during the Cannes International Film Festival. Users (platform: Oculus) are transported into the body and spirit of a Japanese toy robot that is given to an American boy from the suburbs in the early '80s. The film was produced by Felix & Paul Studios in collaboration with the online comedy company Funny or Die. It features a star-studded cast, including Jeff Goldblum.

4.1.5. Carne y Arena / Alejandro Gonzalez Iñárritu

In 2017, the VR installation received a special award from the Academy of Motion Picture Arts and Sciences for its visionary and powerful narrative – interestingly for the first time since Pixar's Toy Story in 1996. The production is set on the US-Mexican border: Users become part of an immigrant group that is captured by a border patrol and then experience how they are treated. The production combines a virtual and spatial experience.

4.1.6. The Void Star Wars Challenge

In 2017, Disneyland Florida announced that it would open Star Wars – Secret of the Empire as the second themed attraction (after Ghostbusters), in which users can interact with virtual characters and other visitors. The Star Wars attraction blends virtual experience with suitable sets that are equipped with interactive touch surfaces to allow for a more powerful tactile experience. The visitors wear backpacks and are therefore able to move freely through the space. The new attraction is a cooperation between The Void and Lucasfilm's immersive entertainment unit, ILMxLab. A number of VR arcades are already run by The Void at Disneyland Florida.

4.1.7. Home – A VR Spacewalk / Rewind

The 15-minute VR experience was produced on behalf of BBC Learning, BBC Science and BBC Digital Storytelling. The production is based on NASA's astronaut training program. It revolves around an emergency situation in which users are required to return from their spacecraft to the International Space Station, powered by a jet pack.

4.1.8. The Cathedral / WDR

The project invites users to enjoy an interactive experience of Cologne Cathedral: They can explore the individual elements and even embark on a trip through time to visit the Cathedral during the Middle Ages or other periods. WDR used the production, which received the Grimme Online Award, to explore the potential of VR. The production was designed for six different platforms.

4.1.9. Safran Nacelles and Airbus

Equipped with a nacelle system by Safran Nacelles, the virgin flight of the Airbus A330neo in October 2017 was the culmination of a 42-month development cycle, so around 18 months faster than usual. In order to achieve this accelerated development time, Safran Nacelles used virtual reality technology combined with CAVE display systems in order to validate assembly procedures, develop ergonomic tools and ensure efficient operator training as quickly as possible, while still improving the working conditions for its team. Use of VR technology led to a 10% cut in tool costs and a 50% reduction in the validation time for industrial milestones. The innovative system was awarded the Safran Innovation Grand Prize in March 2017.

4.2. Selected AR and MR Cases

4.2.1. Augmented Reality Maintenance / Deutsche Telekom AG

The use case 'AR Maintenance' at the Telekom Design Gallery in Bonn illustrates the potential of AR in an industrial setting. Equipped with an AR headset, users receive context-based information and instructions for machine maintenance. Innovative technologies like real-time object detection are used in this context. Sensors, a camera and a microphone collect data that is used as a basis to optimize processes. In 2017, the solution by the Telekom subsidiary T-Systems received the Red Dot Award, the Annual Multimedia Award and the UX Design Award. According to the company, three corporate clients are already using the technology.

4.2.2. Augmented Reality Shopping / Yihaodian

Yihaodian, China's biggest food retailer, has already opened more than 1,000 virtual outlets in the country according to industry reports. They are found at public locations and allow customers equipped with the company's proprietary app to browse through the products and place orders directly. The groceries are then transported straight to the buyer's home.

4.2.3. Project Esper / 3D4Medical

The declared objective of the AR project is to improve training at medical institutions, especially for surgeons. Designed essentially as an AR textbook, it features numerous animations that help students to transfer the information from a two-dimensional setting to three dimensions. Users can interact with the content to access a variety of virtualized perspectives and positions.

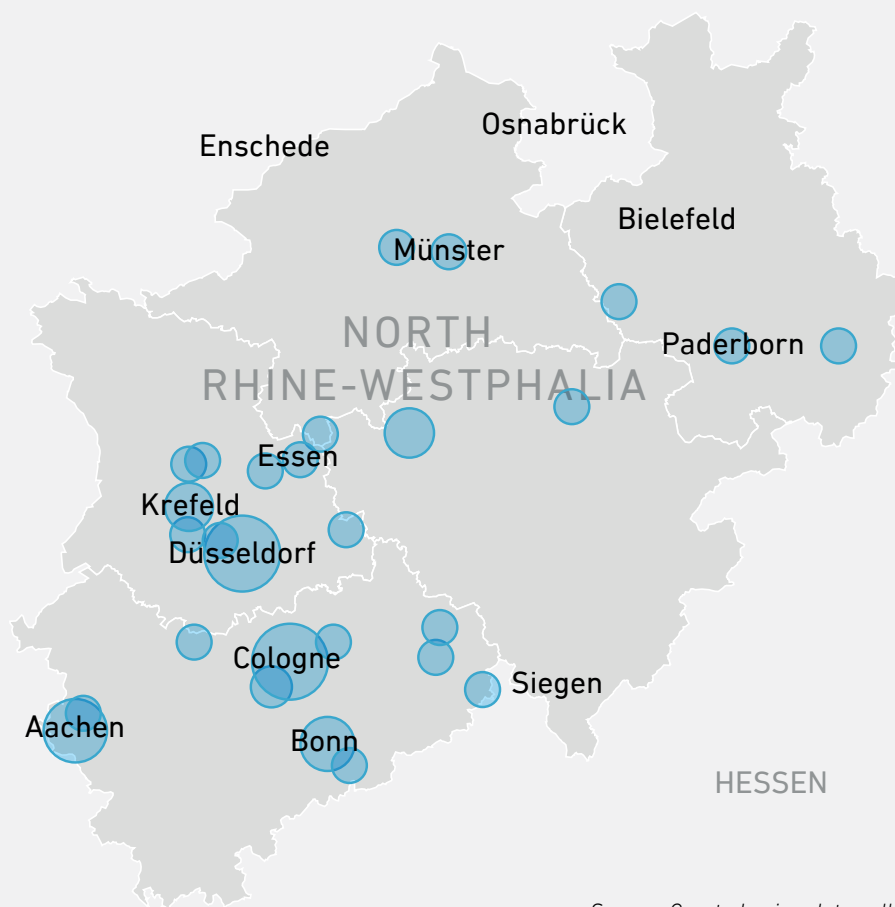
5. THE VR AND AR SECTOR IN NRW

In total, the study identified 101 companies and organizations dealing with the subjects of VR, MR and AR in North Rhine-Westphalia. In addition to startups and moderately-sized SMEs, they also include departments within major corporations pursuing an independent VR/MR/AR strategy or offering products in this field. The following section contextualizes the information on location, company size and age in order to review how representative the responses are.

5.1. Structure of the VR/MR/AR Sector in NRW

Companies within the VR/MR/AR sector in NRW operate in distinctly regional clusters: 24 of the identified companies have their registered offices in Düsseldorf and 46 in Cologne. Other cities trail by a clear margin, among them Aachen (7) and Bonn (5) (cf. Figure 21).

Figure 21: Regional Distribution of VR/MR/AR Companies in NRW



Source: Created using data collected by means of desk research.
The size of the circles indicates the number of companies in the city or region, n=101

A comparison with the information obtained from the online survey shows a quite similar distribution. Here too, distribution is concentrated in larger locations (*cf. Figure 22*).

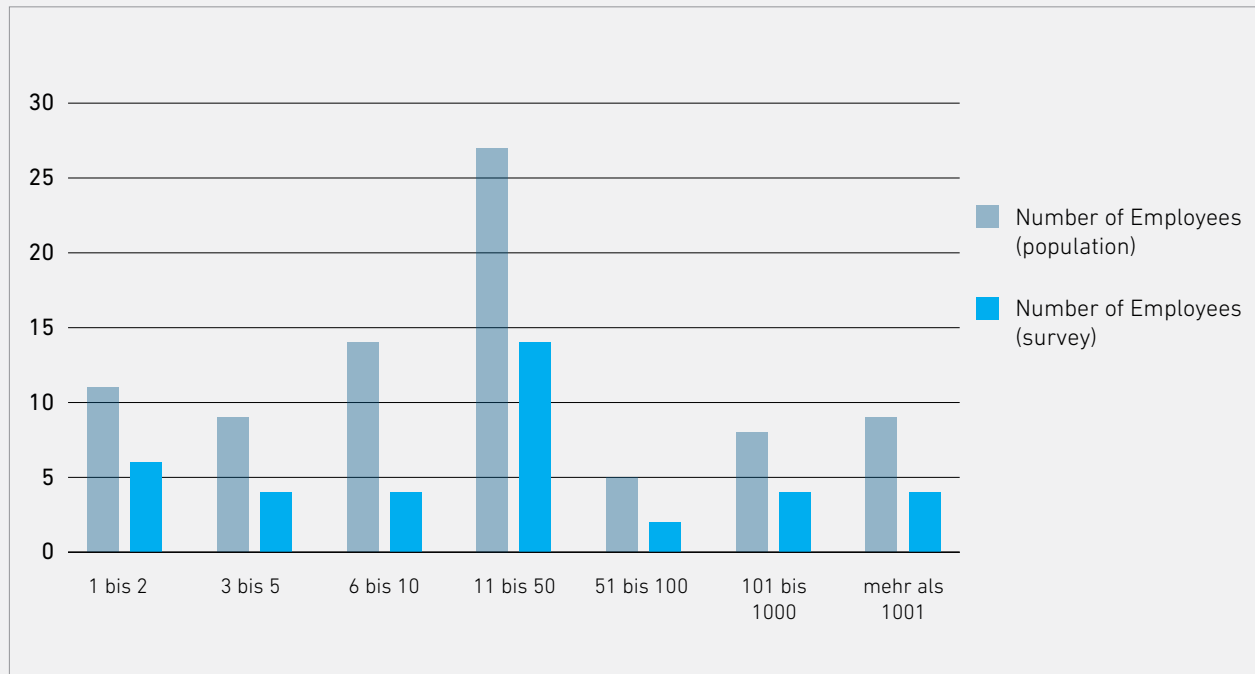
Figure 22: Regional Distribution of VR/MR/AR Companies in NRW (survey)



*Source: Created based on the online survey.
The size of the circles indicates the number of companies in the city or region, n=43*

In regard to size (measured according to the number of employees), it becomes apparent that most of the companies in the sector are quite small. Data collected by the authors shows that one third of the companies have fewer than 10 employees. A quarter of the organizations are SMEs with 10 to 50 employees. Some corporations are also involved in this area; in these cases, however, the actual focus of activities is on areas other than VR/MR/AR. A comparison with the information volunteered by the companies in the survey also reveals a largely identical distribution. Only the representation of companies with 6 to 10 employees is below average in the online survey.

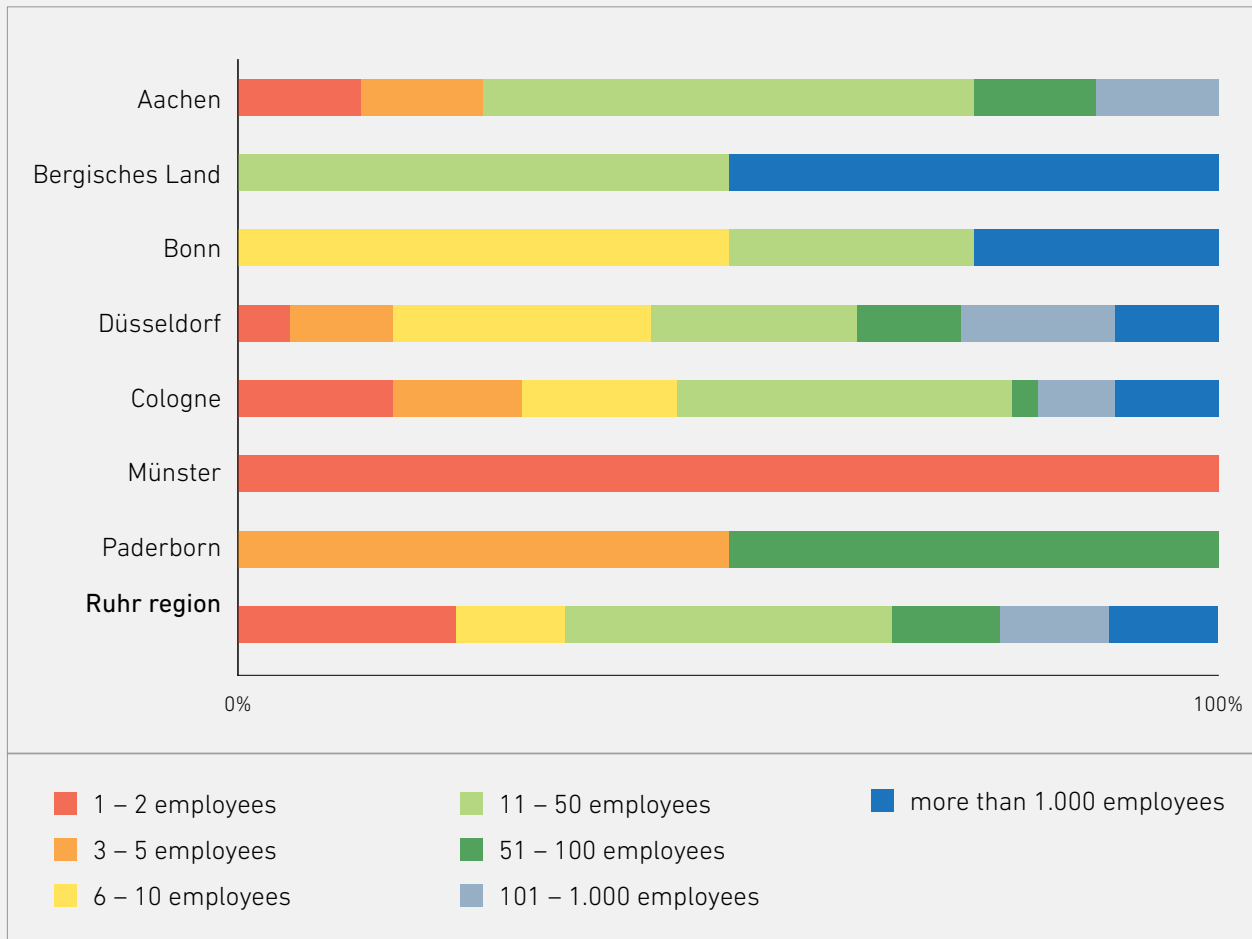
Figure 23: Size Classes of VR/MR/AR Companies in NRW



Source: Population: Own survey, n=101/online survey, n=43

The distribution of companies according to size and region is unremarkable in this context. In the core region of Cologne and Düsseldorf in particular, the size distribution is largely equivalent to the state-wide average.

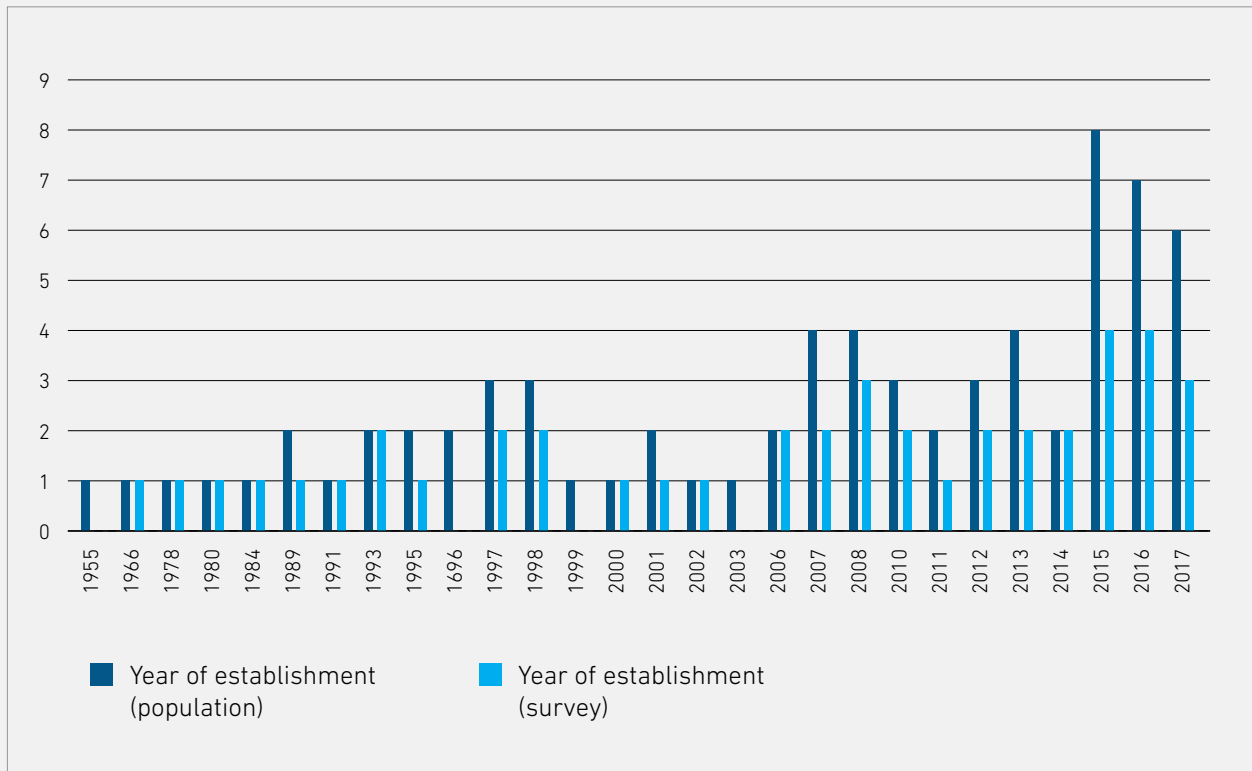
Figure 24: Distribution by Size Class and Region



Source: Created using data collected by means of desk research, n=101.

In regard to startups, it is apparent that the pace has picked up noticeably in recent years: A good quarter of the companies were founded in the last thirty-six months (*cf. Figure 25*). It is also worth noting that numerous companies have operated on the market for more than ten years, which means that they were active in the 'early waves' of VR and are still in operation. Representation of these groups in the survey is above average.

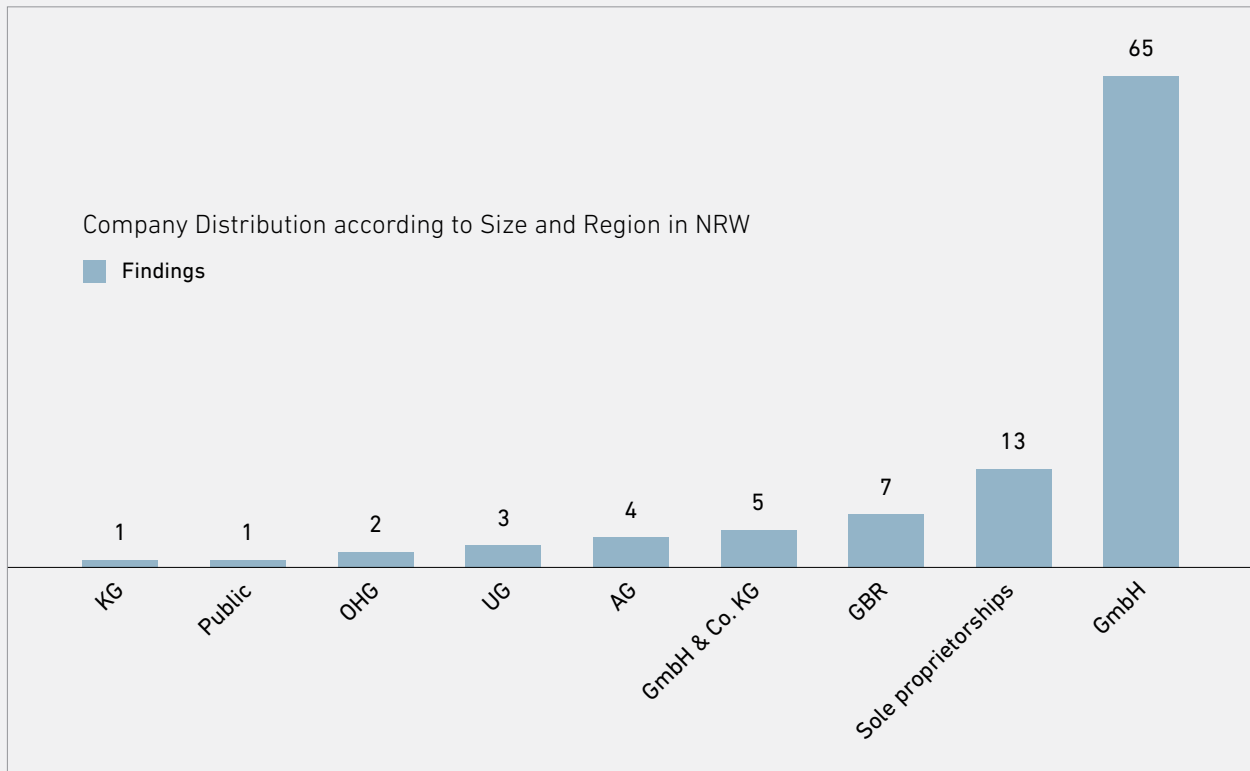
Figure 25: Founding Dates of VR/MR/AR Companies in NRW



Source: Population: Own survey, n=101/online survey, n=43

Overall, the legal forms of the surveyed companies indicates ongoing professionalization within the sector. For instance, only a quarter of the companies are incorporated in 'simpler' legal forms (entrepreneurial companies (UG), general partnerships (OHG), partnerships under civil law (GbR)); limited liability companies (GmbH) are by far the dominant form.

Figure 26: Legal Forms of VR/MR/AR Companies in NRW

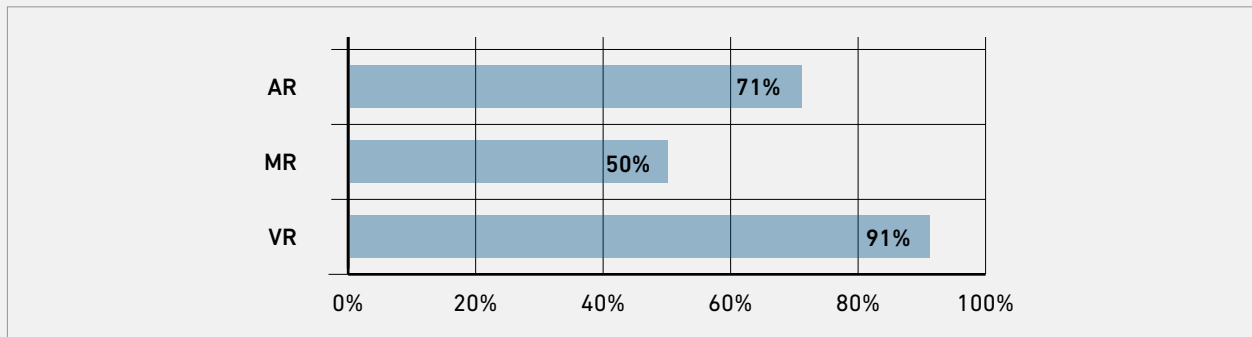


Source: Created using data collected by means of desk research, n=101.

5.2. Activities of VR/MR/AR Companies in NRW

The companies are primarily active in the VR sector. Just under 91% of the companies surveyed stated that their focus is in this area. Nevertheless, many respondents also reported activities in the field of AR. Mixed reality trails by a clear margin, although 50% of the companies did state an involvement in this segment as well. This confirms the study's focus on VR, as well as on MR and AR. The responses also show that the boundaries between the three forms are becoming blurred: Only 30% of the surveyed companies operated in just one of the three categories, and 40% stated that they are active in all three fields.

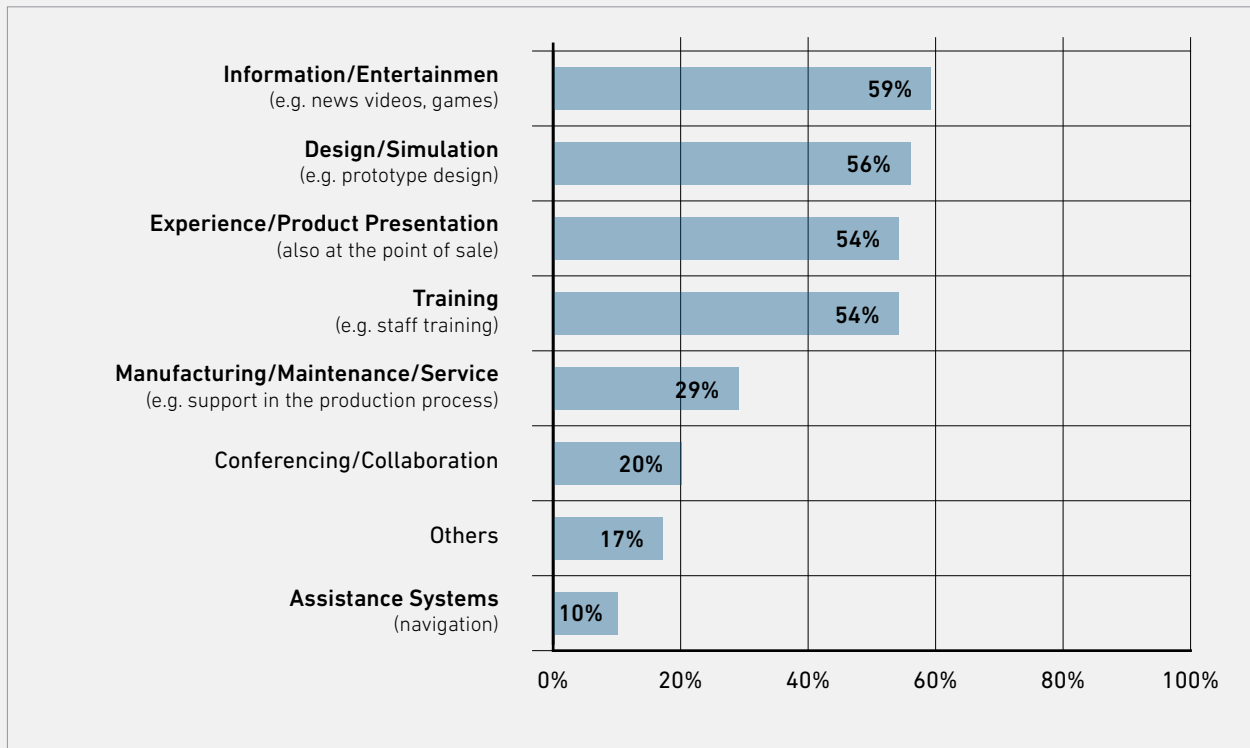
Figure 27: Activities in VR, MR and AR



Source: Online survey, n = 43

With regard to the developed products and solutions, most of the companies (59%) reported that they offer information and entertainment solutions, e.g. news videos or games. An equal number of companies were also active in the field of experience/product presentation. Over half of the companies also provided solutions in the areas of design/simulation (e.g. prototype development) and training (e.g. for staff). Significantly fewer companies stated that they develop or distribute products for the areas of manufacturing/maintenance/service, conferencing or assistance systems (wayfinding etc.). A very small number of companies stated an involvement in technical solutions or system integration for VR, MR or AR (cf. Figure 28).

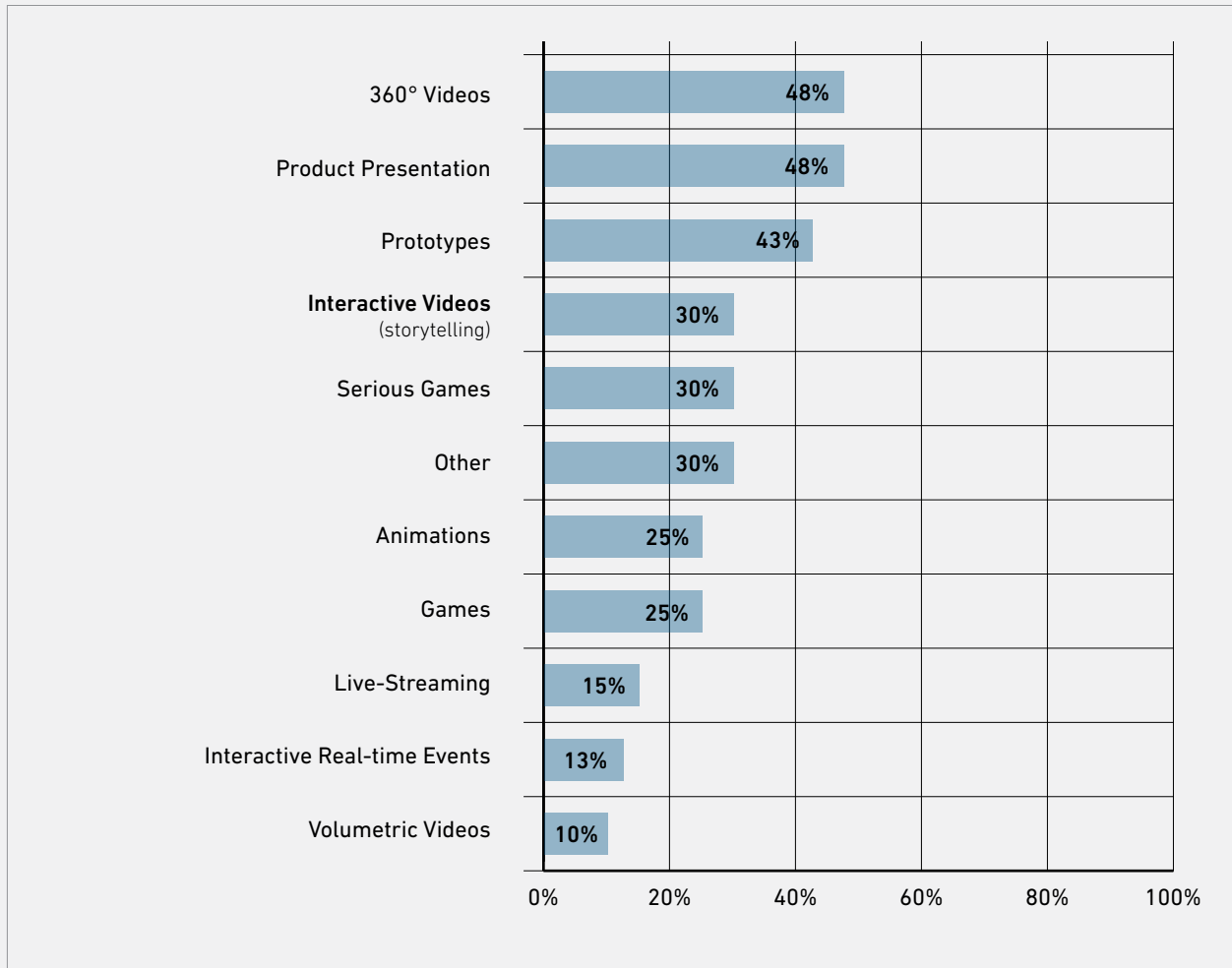
Figure 28: Product Portfolio of VR/MR/AR Companies in NRW



Source: Online survey. Multiple answers were possible, as the companies are able to cater to several use cases at once, n = 41

When asked about the actual products sold by the companies, 360° videos come first. If interactive videos are included, the provision of moving image content lies clearly ahead: 63% of the companies stated that they produce 360° videos, interactive videos or volumetric videos. Just under half of the companies surveyed named product presentations, followed closely by prototype development. Games, serious games and animation featured less frequently. Moreover, few companies are involved in complex applications, live streaming, interactive live events or volumetric video productions.

Figure 29: Formats Offered by VR/MR/AR Companies in NRW



Source: Online survey. Multiple answers were possible, as the companies are able to cater to several use cases at once, n = 40

5.3. Customers and Revenues of VR/MR/AR Companies in NRW

In order to obtain further details about the economic focus, another step asked the companies to name their target sectors, i.e. investigated the sectors in which the companies recruit their customers.⁸ The classification used by the Federal Statistical Office was used to structure the responses (Federal Statistical Office, 2008).⁹

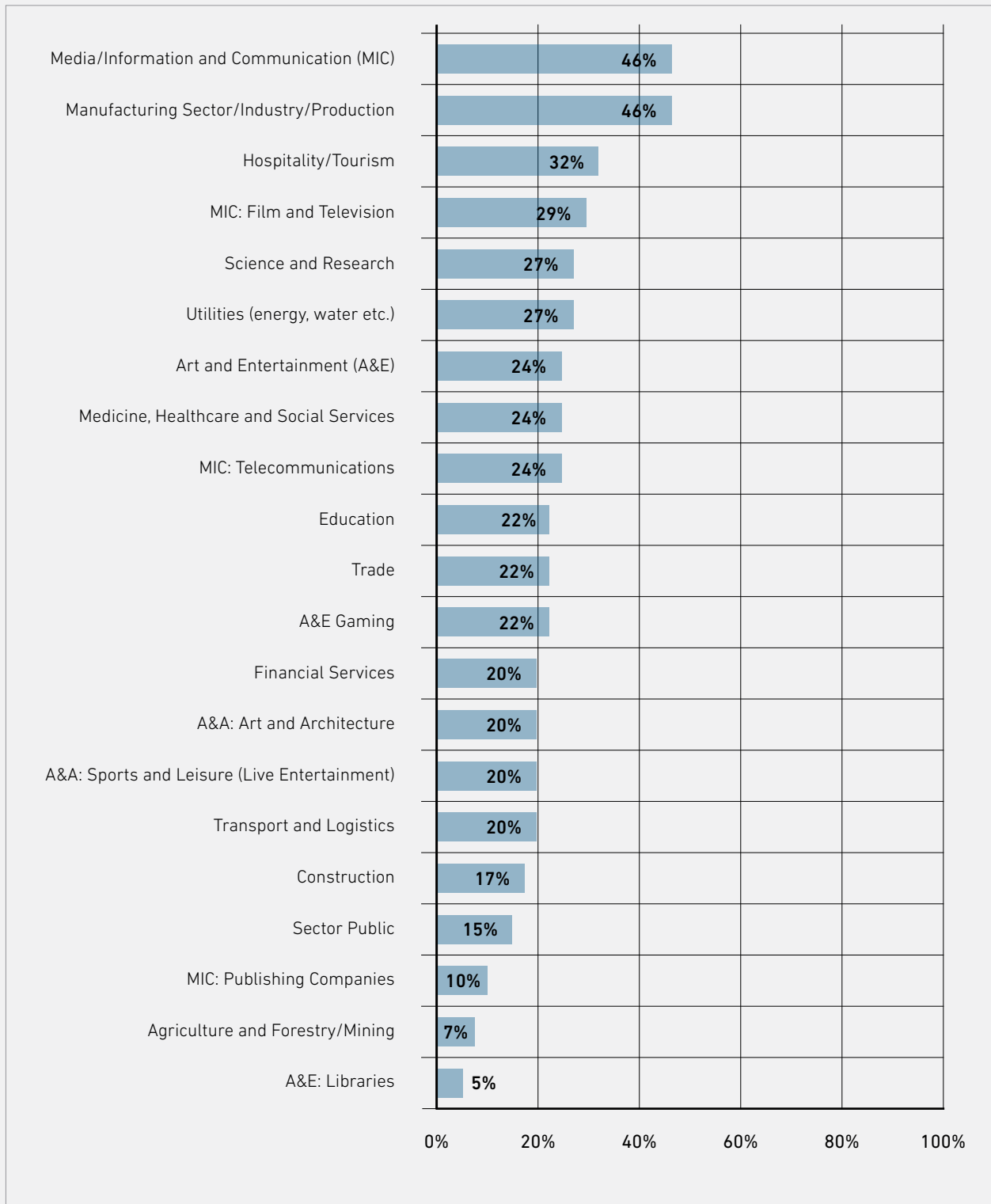
In a consideration of the customers for whom the companies in NRW are active within the population, the sectors of media/information and communication (MIC), as well as art and entertainment, were clearly ahead, with each being named 46 times. They are followed by manufacturing industry/industry/production (27), retail (24), the construction industry (including architecture (named 19 times), education/training (16) and the health sector (12).

These findings are confirmed in the online survey, where merely the segment of art and entertainment features in the responses far less frequently. In the area of MIC, most companies are active on behalf of the moving image sector (film and television), followed by telecommunications companies. Publishing companies only play a minor role in this regard (*cf. Figure 30*).

⁸ Very few companies – apart from TV companies, for example – distribute their products directly to consumers, and instead offer products that are used by branded companies in their communication with end customers. The B2B aspect therefore appears appropriate.

⁹ For the purposes of legibility, some industries that are largely insignificant for this study are grouped together.

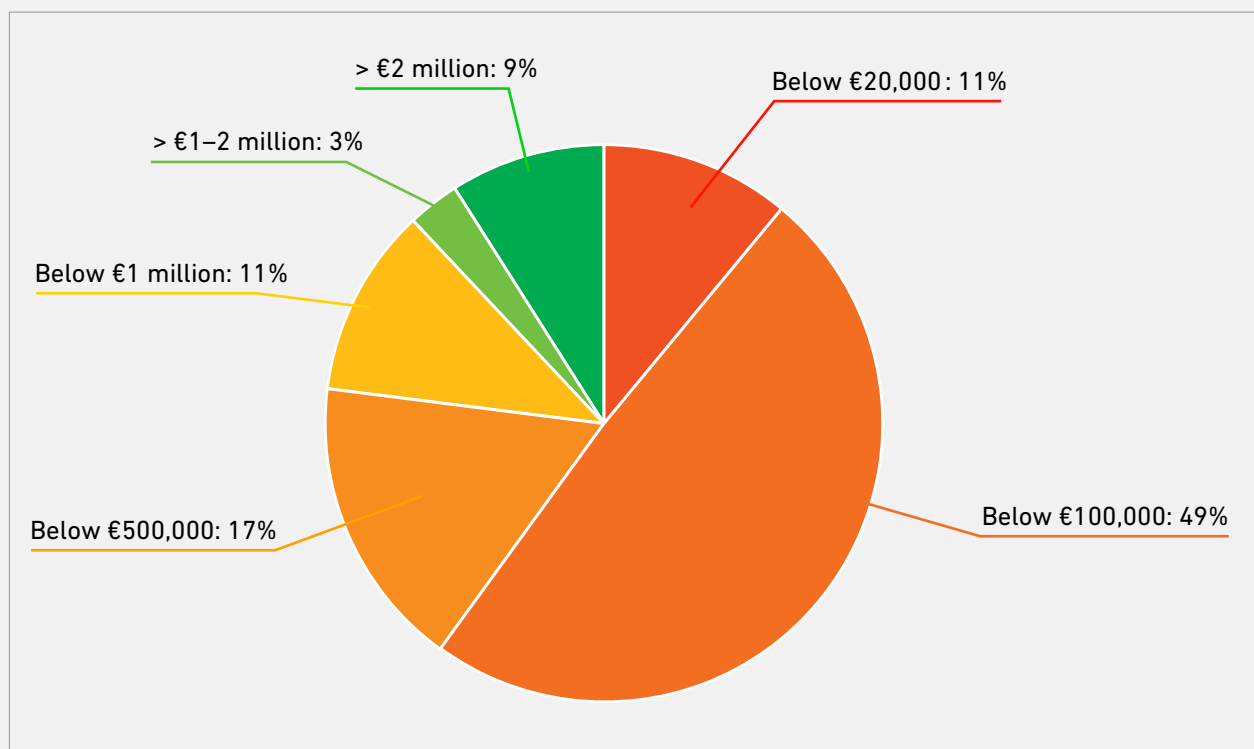
Figure 30: Target Industries of VR/MR/AR Companies in NRW



Source: Online survey. Multiple answers were possible, as the companies are able to cater to several use cases at once, n = 41

The survey shows that there are some instances in which quite substantial sales are generated with these new technologies. For instance, almost half (49%) of the companies surveyed generated less than €100,000 in 2016. Moreover, 11% reported turnover of below €20,000 from VR/AR/MR. 17% of the companies still reported VR/MR/AR-related sales of more than €100,000, but less than €500,000. In total, eight of the surveyed companies generated sales above this threshold. Three companies even realized revenues of over €2 million with VR/MR/AR. These figures indicate that the industry is still developing strongly. At the same time, there is a small number of well-established companies, most of which have operated on the market for a very long time. The companies generating sales in excess of €1 million were founded between 1989 and 2002 and have more than 10 employees. Their predominant focus is on the production of VR, MR and AR – only one company claimed to be specialized in AR.

Figure 31: Annual Sales by VR/MR/AR Companies in NRW 2016



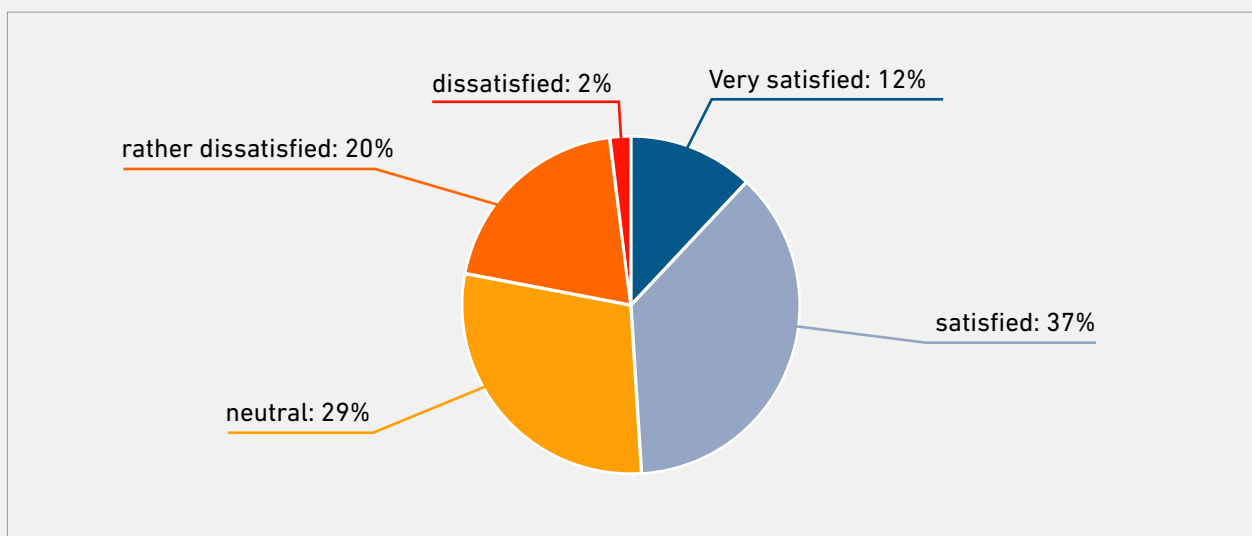
Source: Online survey, n = 35

Explanations for the generally low sales are contained in a survey that EDFVR e.V conducted of its member firms in 2017. In this regard, 55% of the respondents reported a budget of less

than €40,000 for AR productions (43% even below €20,000). A similar situation is apparent among VR projects; 69% of the respondents estimated the project budgets to be less than €40,000, while 48% reported budgets of below €20,000. It follows, therefore, that the majority of companies can only generate substantial sales by becoming involved in a large number of projects (EDFVR, 2017: 11f.).

Accordingly, it is hardly surprising that the companies surveyed are not particularly satisfied with their current VR/MR/AR activities. Recording an average score of 2.63 (Likert scale from 1 (very satisfied) to 5 (dissatisfied)), the companies are generally rather satisfied with their business development. But this result is still astonishingly low for a trend topic that is perceived to be highly attractive by the general public. At present, the translation of general interest into actual products appears to be less than satisfactory.

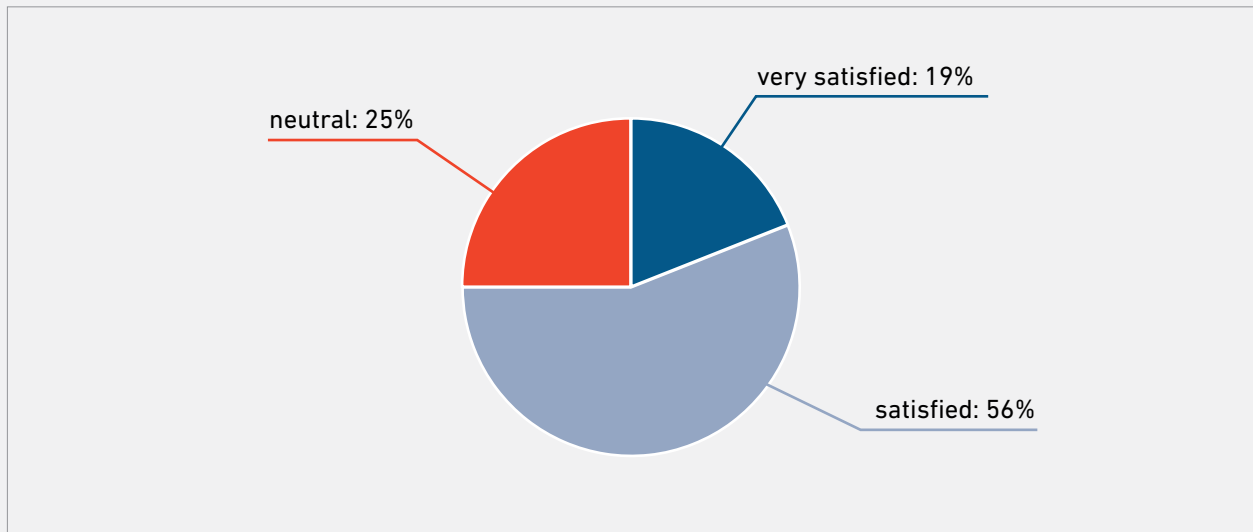
Figure 32: Satisfaction with Current VR/MR/AR Activities



Source: Online survey, n = 41

Nonetheless, the respondents do believe that their business prospects are likely to improve substantially. When asked to predict developments in the coming 18 months, most of the companies surveyed rated their satisfaction with a considerably more positive score of 2.06 (same scale, see above). None of the companies anticipated that they would be dissatisfied or very dissatisfied with their business development in 18 months (cf. Figure 33).

Figure 33: Satisfaction with VR/MR/AR Activities in 18 Months



Source: Online survey, n = 41

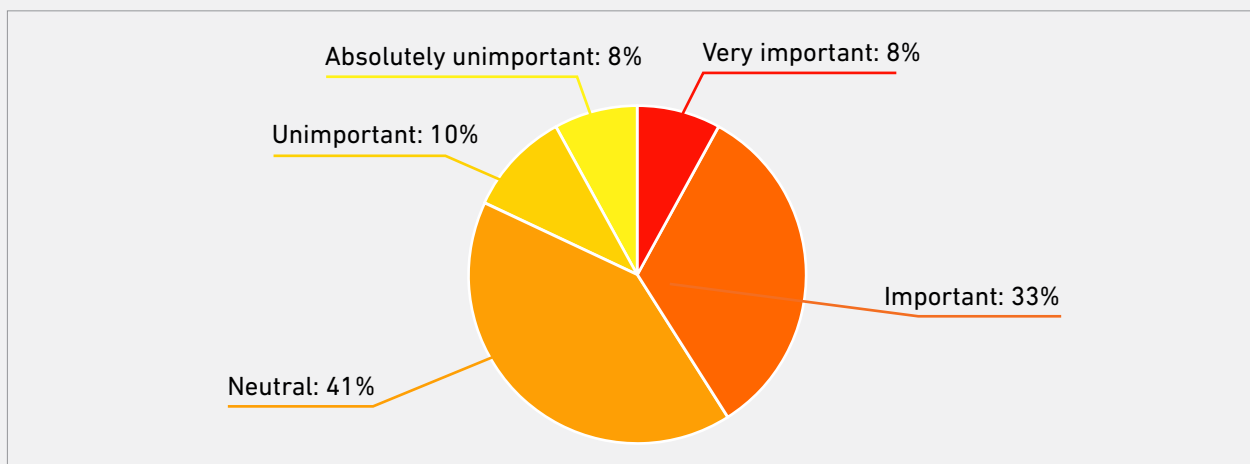
5.4. Development of the NRW Location

5.4.1. Significance and Evaluation of the Location from the Stakeholders' Perspective

The virtual, mixed and augmented reality sector is characterized by a strong national and international focus and networking between the individual stakeholders. This became apparent in the expert interviews and was substantiated by the findings of the survey.

For instance, only 40% of the companies surveyed generally assign an important or very important role to the location of their company for the success of VR/MR/AR activities (*cf. Figure 34*). Most responses were neutral, while a minority of 18% rated the geographic location as unimportant or very unimportant.

Figure 34:
Importance of a Specific Location for the Success of VR/MR/AR Activities



Source: Online survey, n = 39

The assessment is consistent with the largely national and international focus of most providers' corporate activities. The majority of companies stated that they recruit their customers at national or international level. Only four of the 39 responding companies stated that they operate mainly within a regional sphere. This impression repeats itself if, after including suppliers and services providers, the companies are asked

about relevant competition, cooperation with research institutions or staff training. The companies only reported a stronger regional focus in the recruitment of new staff, although the national and international levels were mentioned by just under half of the companies and are therefore relevant (cf. Figure 35).

Figure 35: Geographical Focus of Corporate Activities

	%	regional	national	international	Ø
Staff recruitment		51	28	21	1.69
Integration of suppliers/service providers		21	41	38	2.18
Collaboration with research & development		18	38	44	2.26
Further training		15	38	46	2.31
Customer acquisition		10	41	49	2.38
Differentiation from competitors		8	45	47	2.39

Ø Arithmetic mean (1= exclusively regional focus; 3 = exclusively international focus)

Source: Online survey, n = 39

A further differentiation becomes apparent in the rating of concrete locational factors in NRW. For the choice of specific location, good access to potential employees is rated as especially important (value of 1.97 on a five-level Likert scale from 1 (very important) to 5 (absolutely unimportant)). This is followed by access to customers in the region (2.08) and to freelancers for individual projects (2.21), networking with other local VR companies via meetings and conferences (2.26) and the regional exchange of information via groups, events or associations (2.28). Proximity to the creative and media industries is also regarded as important. The score of 2.38 appears very meaningful if one considers that many of the companies are not situated in one of the media clusters in NRW. This factor becomes even more important when considering the companies in Cologne, for example: The firms located there rate this question with 1.65, making it one of the most important factors.

Other aspects are less significant, comparatively speaking, although the ratings remain somewhat positive: Proximity to research institutions (2.54), location promotion, i.e. financial

support, (2.64), proximity to technical service providers (2.77) or other companies in the sector (2.82) and marketers (2.9). Significance for the fulfilment of projects was rated as less important, as most of the respondents stated that they operate largely at national level. This means that although technical service providers can be 'sourced' in the region, cooperation across regional boundaries still makes sense in most cases.

Proximity to other startups (3.08) records the lowest score, although it also changes if the companies questioned were founded in the last three years: These companies rate this factor with a score of 2.54, therefore making it equally important as proximity to research institutions.

Figure 36: Significance of Location Factors for VR/MR/AR Companies in NRW

	Ø
Access to potential employees for VR/MR/AR at the location	1.97
Customer proximity	2.08
Access to potential freelancers for VR/MR/AR at the location	2.21
Networking between the VR/MR/AR companies at the location (meetups, conferences and similar)	2.26
Sharing of information in regional associations and groups or at events	2.28
Proximity to the media and creative industries	2.38
Proximity to research institutions (basic and/or applied research)	2.54
Location promotion (financial and/or expertise)	2.64
Proximity to technical service providers for VR/MR/AR	2.77
Proximity to other VR/MR/AR companies	2.82
Proximity to marketers of VR/MR/AR	2.90
Proximity to startups (also in other sectors)	3.08

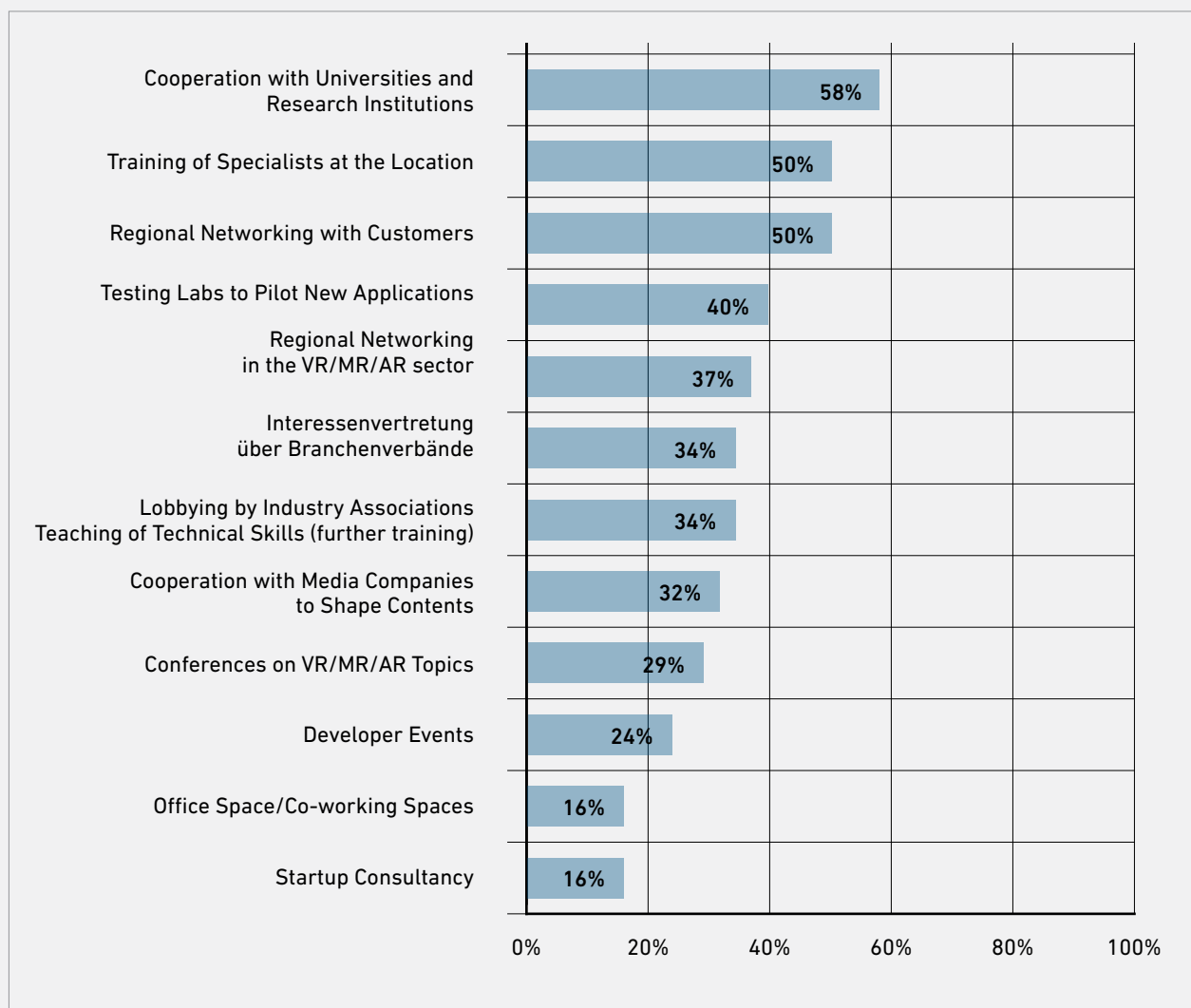
Ø Arithmetic mean (scale from 1 = very important 5 = absolutely unimportant)

Source: Online survey, n = 39

5.4.2. Development Needs in NRW from the Stakeholders' Perspective

Companies and NRW report very different needs in regard to promotion or support measures that are designed to drive the development of the VR/MR/AR sector in NRW.

Figure 37: Development Needs from the Perspective of VR/MR/AR Companies



Source: Online survey, n = 38

Initially, the intensification of cooperation between universities/research institutions and industry is considered to be a priority (58%). This was also confirmed in the expert interviews. Here, the established players expressed a desire for stronger representation in calls for scientific research projects with practical relevance. Regional universities are not included

often enough in this regard. The universities agreed with this assessment – faced with the rapid technological development, universities are experiencing difficulty 'keeping up with their basic research' (Interview with T. Kuhlen, RWTH, 2017), so application-oriented projects should be expanded to a greater extent. This is consistent with other findings that indicate an inability to translate strong basic research in the area of VR into commercial success in Germany (*Heng et al., 2015*).¹⁰ Aside from the development and implementation of innovative solutions, access to talented recruits is also perceived as an important benefit of networking with universities (see below). This can also lead to spin-offs.

Moreover, precisely half of the companies surveyed stated the urgency of establishing networks with customers in the region. The survey and the expert interviews identified customer acquisition as a key factor for the development and establishment of the VR/MR/AR sector in NRW. The major platform providers (Sony, Oculus/Facebook, Samsung, HTC...) were largely seen as the key players in the B2C market. They were tasked with developing better devices and achieving more widespread penetration as a means of preparing the market. Only a few players, among them Deutsche Telekom AG, reported plans to launch a proprietary platform for VR content as a means of developing the market. Significant hopes were placed in the Christmas period 2017 especially, which was anticipated to feature better devices and applications (mainly games). From the NRW perspective, however, these activities could only be controlled within the framework of integral support, e.g. for the games industry.

The respondents expressed the widespread belief that the B2B market would remain more attractive in the short term, as there are already established use cases and therefore revenue opportunities. In regard to the central aspect of customer proximity, reference was made in particular to the geographic proximity to numerous large corporations in NRW, as well as to larger SMEs from a variety of industrial branches. This facilitates sales, for instance, because it is easier to pitch projects and organize demonstrations. This is only substantiated to a very limited extent when considering the media sector. For instance, the most important customers in the TV segment are located in Mainz, Munich or Strasbourg, and not in Cologne. What's more, the major players at the location were perceived as isolated operators.

The lack of clear awareness of use cases for VR/MR/AR was seen as the greatest obstacle

¹⁰ Germany holds a 7% share of the market for 3D objects in the field of augmented reality and hence comes third in a global comparison, trailing behind China (14%) and the United States (21%). The Max Planck Society has released a good 3,000 scientific publications in this field, more than any other scientific institution worldwide at this time (*Heng, Hörster, & Karollus, 2015*).

to customer acquisition – although many customers have already heard or read about the technology. Many of the experts interviewed reported that a demonstration/introduction to the issue is necessary during initial contact in order to develop the actual cases. This obstacle does not apply to companies that have already acquired experience in this field.

Precisely 50% of the respondents would also like to see improvements in the education and training of talent at the location. Overall, however, the respondents rated the training opportunities in NRW as good, stating that the mixture of universities and public and private sector institutes of higher learning has already created a diverse education sector. Nevertheless, there are still bottlenecks in some areas – also beyond the concrete needs of the VR and AR sector. They include courses for programmers that teach a stronger understanding of concept and design (compare equivalent courses for 'creative coders'). In addition, many respondents stated the need for specialized skills, especially among developers for the Unity and Unreal Engines, as well as for mobile applications. There was also widespread agreement between the respondents that VR, MR and AR employees are currently unable to draw on a clearly defined production process, i.e. requirements. They therefore called for the communication of integral knowledge, which not all employees will possess, for instance if they come from the classic media and IT sectors that usually focus on individual stages of production.

The respondents also complained that VR-related material is insufficiently included in the curricula of media professions, for instance in the training of authors, camera operators or directors. They did admit nonetheless that in view of the still limited and uncertain use cases, personal motivation is a deciding factor in addressing the issue and that this will usually take place at the same time as an involvement in more traditional assignments. At present, it is neither economically viable nor advisable for employees in content production to focus exclusively on the fields of VR, MR and AR.

40% of the companies called for testing labs to pilot new applications and demonstrate them to potential new customers. This would be a low-level opportunity to 'evangelize' customers and to demonstrate or realize projects in the short term. A model here is the XR Lab of the Digital Hub Cologne and the EDFVR e.V, as is the planned Center for Immersive Technologies at the Cologne Game Lab/TH Cologne on Schanzenstraße. Broad access for customers and producers was mentioned as an important factor in these concepts, as it would reduce inhibitions and demonstrate openness for future developments.

Furthermore, networking among companies (37%) and improved lobbying by industry associations (especially with a regional focus) are also considered important. They should

also strengthen regional networks in line with the state government initiative to position Cologne-Düsseldorf as 'Rheinland Valley'. This is because not even the two leading locations in NRW occupy a position comparable to other industrial hubs that are competing at international level, which means that they must strengthen their cooperation in order to succeed. The experts expressed the belief that other media locations with regional initiatives – among them Next Reality in Hamburg or Virtual Reality Berlin-Brandenburg – are one step ahead. For instance, the Berlin-Brandenburg association organizes regional workgroups on relevant topics, as well as a business-oriented trade show (VR Now Con). Located in Cologne, EDFVR e.V. is set up as a national association, but might be open to talks on establishing a 'regional group'.

32% of the companies surveyed also expressed an interest in collaborating specifically with media companies, which again emphasizes the future potential of more content-based applications.

While the established companies that have been active on the market for decades (*cf. Chapter 5.1.*) emphasize the business potential of the location in particular, representatives of more recently established firms highlight the importance of a well-developed startup scene, especially in Cologne and Düsseldorf. They appreciate the opportunity to share their experiences of foundational and early-phase issues with other startups. The micro-clusters of companies that have evolved from concrete collaboration between individual companies at specific locations in the cities were also perceived as very important. The needs are consistent with the questions that startups will typically face: Suitable real estate (preferably with the opportunity to network with companies operating in complementary fields within a 'sub-cluster'), support during the foundation phase (how to manage bureaucracy), sharing of experience with other startup, as well as legal counselling, e.g. with a view to international cooperation/licensing issues.

6. DERIVATION OF RECOMMENDATIONS FOR ACTION

6.1. Stronger Networking with Universities and Research Institutions

It might be possible to create networks between universities and companies based on established forerunners like the Virtual Dimension Center (VDC) Fellbach, which has used its network to coordinate application-oriented projects and therefore also to drive research projects for several years. A more recent example would be the AVARE Network at TU Chemnitz; in NRW, RWTH Aachen also has a network that offers contact to service providers and partners in the realization of projects. These institutions are already operating successfully and provide a strong focus on 'traditional industrial sectors' that have already developed specific use cases and therefore demonstrate a willingness to purchase services. The current plans for a regional Visual Computing Group at important universities in North Rhine-Westphalia might be a first step in this direction, although the organizers have stated that its networking will focus on the scientific community.

6.2. Training of Specialists at the Location

Despite the advisable policy of training developers and other professions (regardless of the needs of the VR/MR/AR sector), it appears sensible to offer a course in continuous vocational training, e.g. for 'digital producers', especially if we consider that increasing numbers of employees are likely to be needed for media-related VR/MR/AR applications, although they originate in other professional fields and will continue to work there. In view of the rapid pace of technological development, it seems likely that on-the-job training will become necessary, as other forms of training would be too slow or unable to respond adequately to the very specific needs.

Moreover, suitable measures should be taken to raise awareness and cultivate acceptance of VR/MR/AR within the creative industries. A first step would be to make film and media students more aware of the potential inherent to the medium during training, e.g. via pop-up movie theaters or VR arcades. It would also be worth considering the launch of an open producer program to bring interested journalists, editors or camera operators from all kinds of organizations into contact with the new technology. This might contribute to dismantling the organizational silos within the media sector.

6.3. Regional Networking with Customers

A variety of tools can be used to promote networking with customers in the region:

- The organization of informational events and programs would seem a sensible, accessible approach to begin with. It should take place in cooperation with established business organizations (e.g. the chambers of industry and commerce or industry associations). This would ensure the aforementioned 'evangelization' of other business communities.
- It is also important to create testing labs and demonstration spaces. Promising steps in this direction have already been taken in Cologne. With a view to the distribution of the sector in NRW, it would be worth considering whether a similar institution might be beneficial in the metropolitan region of Düsseldorf and possibly in Bonn and Aachen as well.
- The third element that is recommended is addressing customers at events and trade fairs. The establishment of a leading fair for the sector is an important factor. In this context, the Digility Conference has been frequently cited as a "regional poster child", and it could be used as a basis to build upon. It is equally crucial to attend the relevant events in the target industries, namely the ones that focus on issues of the digital transformation (e.g. Dmexco, D!conomy).
- Given the significant costs that are currently associated with VR/MR/AR products and their considerable complexity, personal contacts and advice are vital when launching new projects. It therefore seems to make sense to establish an institution along the lines of the VDC in Fellbach that brings together universities, research institutions, industrial partners and key users and allows them to share their technical expertise. Building this kind of institution could help to tap into additional potential, especially in the industrial B2B segment of 'current users'.
- Finally, to reward outstanding achievements in the field of AR/MR/VR, it would be worth considering strengthening visibility by establishing a prize with international appeal, e.g. as part of the German Developer Award or the 'lead trade show in the region'. Doing so would not only radiate among current customers, but also address other particular needs (e.g. talent recruitment).

6.4. Stronger Networking within the Sector

Measures that foster an exchange of content and business interests would be recommendable

in order to strengthen networks between the players.

- High-level, thematically focused conferences or workshop discussions along the lines of a 'community of practice' could address the need for an improved exchange of ideas between specific professions, for instance in the area of UX design for VR applications or journalistic storytelling. Although individual, established events already take place in NRW (e.g. the Clash of Realities Conference by the Cologne Game Lab), most experts were insufficiently aware of their existence. It would be worth considering the organization of dedicated events in the supporting program of a lead trade show like Digility.
- Open formats like meetups that address an interested community and focus on a variety of topical fields should be organized as a low-level method of building networks between businesses. Overall, the number of offerings appears to be sufficient. A more pressing aspect would be to raise awareness for the current events and to seek to build bridges to related industries (e.g. the numerous developer events in NRW).
- Finally, a powerful, regional industry association is a crucial factor for effective networking. For a large state like NRW, establishing this kind of organization is relatively difficult, but it would certainly be worth considering creating a suitable association for the core area of Cologne-Düsseldorf at least (which would of course be open all stakeholders). The support of regionally differentiated initiatives might also be advisable (similar to RWTH Aachen's plans to establish its own euregio-centered association that includes SMEs and universities from Belgium and the Netherlands as well).
- This kind of organization could then drive marketing of the topic (and hence the penetration of additional customer segments), as well as networking at international level: As shown in Chapter 5.4, many companies operate internationally. In this context, it seems to make sense to build upon established international contacts (e.g. between the City of Cologne, also the Cologne Chamber of Industry and Commerce, and the startup scene in Tel Aviv). Doing so would promote stronger ties with the research community, as many projects by universities and scientific institutions have an international and not just regional focus.

6.5. Dedicated Support Measures for Media-related Productions

While functioning value-added systems have already emerged in industrial applications, this applies only to a very limited extent to media-related VR/MR/AR applications. It would

therefore be worth considering introducing a targeted support system to help productions or companies that are active in this field. A factor that was emphasized in this context was the added capital that is required for VR productions, which means that current funding programs (e.g. the €10,000 stipend available from the Mediengründerzentrum NRW) are unlikely to be sufficient. Moreover, consultancy needs may emerge for specific content issues that are not covered effectively by 'general' incubators and co-working spaces etc. that might make it advisable to establish a 'technical program' for VR/MR/AR startups.

Individual respondents also called for the promotion of content-based productions to help bridge the nascent phase of market development and hence to ensure that the full creative potential of VR/MR/AR is exploited. This requires the creation of suitable framework conditions for substantial, targeted and efficient support measures in the various sub-areas that are relevant to VR/AR. Besides the provision of suitable funding guidelines (e.g. for the games segment), it would primarily be necessary to ensure that the project lifetimes and administrative workload associated with the funding programs are consistent with the opportunities and needs of the highly dynamic market development and that they are accompanied by tailored consultancy services for industry players. For example, the NRW Film and Media Foundation's support program for digital content, which has been running since 2011, would provide a suitable program in this sense, although it would require access to greater funding.

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