Unfolding Concerns about Augmented Reality Technologies: A Qualitative Analysis of User Perceptions

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Abstract. Augmented reality (AR) greatly diffused into the public consciousness in the last years, especially due to the success of mobile applications like Pokémon Go. However, only few people experienced different forms of augmented reality like head-mounted displays (HMDs). Thus, people have only a limited actual experience with AR and form attitudes and perceptions towards this technology only partially based on actual use experiences, but mainly based on hearsay and narratives of others, like the media or friends. Thus, it is highly difficult for developers and product managers of AR solutions to address the needs of potential users. Therefore, we disentangle the perceptions of individuals with a focus on their concerns about AR. Perceived concerns are an important factor for the acceptance of new technologies. We address this research topic based on twelve intensive interviews with laymen as well as AR experts and analyze them with a qualitative research method.

Keywords: Augmented reality, qualitative user study, privacy concerns, security concerns, social consequences.

1 Introduction

Augmented reality (AR) gained much attention in the public in the last years, especially due to the success of mobile applications like Pokémon Go [1]. Since the origins of AR technologies in 1968 [2], there was a consistent technical development of AR hard- and software. However, the technical development of AR lacks accompanying research about user perceptions, attitudes and behaviors. Already in 2005, Swan and Gabbard [3] postulated the need to further develop AR systems from a technology-centric medium to a user-centric medium and demanded user-based experimentation. Comparable results are found by Harborth [4], who finds that the majority of research on AR deals with technical aspects and developments and only few user studies and evaluations are conducted. In addition, Dey et al. [5] report on ten years of user studies published in AR outlets. They find that most of these studies are formal user studies, with little field testing and almost no heuristic evaluations. The majority of existing

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studies on augmented reality focuses on the behavior of users interacting with the technology, especially in laboratory environments.
Besides the prevailing gap in current research on AR, it is important to investigate this technology due to its potential impact on all aspects of individuals' daily lives. Tim Cook, CEO of Apple, states that *"[...] it will happen in a big way, and we will wonder when it does, how we ever lived without it. Like we wonder how we lived without our phone today"* [6]. This opinion is substantiated by an increasing activity in the mergers and acquisitions (M&A) market, where large technology companies like Apple or Snapchat are buying small specialized AR firms [7, 8]. Furthermore, AR is experiencing an increasing relevance in the B2B sector by providing substantial efficiency gains [9]. Thus, it is relevant to investigate the interaction with AR and the implications of using AR as early as possible. In summary, the current state of research and the importance of AR as an innovation make it necessary to conduct more user studies on AR in order to analyze users' needs and concerns. In contrast to quantitative research, a qualitative method makes it possible to investigate a wider horizon of possible perceptions and attitudes of individuals that previous research did not consider. Therefore, we investigate the perceived concerns of users with regard to AR technologies based on a qualitative method, called grounded theory method (GTM) [10]. The results can serve as a starting point to evaluate and foster market adoption as well as future developments of AR technologies.
The remainder of this paper is structured as follows. We review related work in Section 2. The methodology is described in Section 3. The results are presented in Section 4. Section 5 contains a discussion of the results. We conclude with Section 6.

2 Literature Review

Past and current research on AR is mainly technical. Comparable research investigating the potential and actual users of AR is relatively rare [3–5]. Most of the existing user studies follow a quantitative research method and investigate one specific case of an AR technology using known theoretical models and construct operationalizations like technology acceptance models or privacy concerns (e.g. [11–17]). Partially, studies complemented quantitative approaches with qualitative methods. For example, Grubert et al. [18] investigate user reviews for AR browser, focusing on negative comments and clustering these comments with regard to certain application features. Olsson and Salo [14] mix open questions with numerical evaluations in an online user survey to investigate general acceptance issues and user experiences with respect to mobile AR. Haugstvedt and Krogstie [13] investigate acceptance factors of a mobile AR application for cultural and historic information in cities. First, they employ a quantitative approach based on a technology acceptance model for hedonic information systems to test their adapted model. Second, they complement this analysis with qualitative interviews with users who actually interact with the application. Besides these mixed-method studies, we could only identify three studies that employ a pure qualitative research method. Ross and Harrison [19] assess technology acceptance factors of a specific AR application based on face-to-face focus groups. Olsson et al. [20] use contextual

interviews (i.e. in the natural environment of the research object, in this case shopping centers) to investigate their expectations and requirements for mobile AR applications. The only study which applies a GTM is the one by Anuar [21] who investigates mobile AR apps for tourism and how such apps influence the experiences of users. Since our research does not focus on one specific application, it provides a higher level of analysis, indicating that the results hold for a variety of different AR technologies. In addition, perceived concerns of AR users are seldomly included in existing analyses. We identified only two articles dealing with one dimension of concerns for the case of Pokémon Go, namely privacy concerns. First, Harborth and Pape [11] specifically focus on the privacy concerns of actual players of the game. They find that although privacy concerns are relatively high, people are still playing the game. This indicates that benefits potentially outweigh the concerns. Therefore, as long as developers can address current concerns with regard to a missing added value of AR, it is possible that users will still adopt AR technologies in light of privacy concerns. The results by Rauschnabel et al. [22] indicate similar conclusions. They find that privacy risks have no significant effect on the attitude towards playing Pokémon Go. Besides these articles, other analyses of the different concerns could not be found.

3 Methodology

Our qualitative research approach relies partially on techniques of the GTM [10]. The GTM constitutes an inductive and comparative methodology for the development of theory grounded in systematic data collection and analysis. The theory involves an iterative process, moving back and forth between data gathering and data analysis; hence, it constitutes focused data gathering and makes the analysis more theoretical. At the center of grounded theory lies the constant comparative method, that is, new data is constantly compared with previous data to draw conclusions from similarities and differences within the data. We apply techniques from the constructivist grounded theory by Charmaz [23]. Constructivism assumes the existence of multiple social realities constructed by the research subject and the researcher and aims to interpret and understand the meaning of the constructed reality [8]. Since we think that interaction effects between researcher and interviewee are important to account for, we lean towards the constructivist GTM by Charmaz [23] in our research. GTM is a commonly used approach in the Information Systems (IS) domain for conducting qualitative research [24]. In a recent article, Wiesche et al. [24] provide a classification of 43 articles using GTM in the major IS outlets. The GTM is mainly supposed to generate a theory for a certain phenomenon under investigation. However, another purpose of GTM is to create a rich description of a phenomenon, in our case the possible concerns of individuals with respect to AR technologies. Since the GTM makes it possible to understand a certain problem from a variety of different perspectives, it is well suited for analyzing user perceptions about AR to generate specific recommendations for AR hardware and software developers to address these issues. We provide an overview of the single steps in the following sections.

3.1 Research Problem

As described earlier, the research objective of this paper is to analyze the individuals' concerns about AR technologies. For that purpose, we gathered data through intensive interviewing and created a semi-structured interview guide for conducting the interviews. Our interview guide is characterized by open questions and a high level of flexibility. This means, that we changed the interview guide according to new insights from already conducted interviews, e.g. by including interesting questions which came up in prior interviews. During the first interviews, our questions were rather generic. We asked interviewees about their personal experiences with AR, their beliefs about why AR is used, which application areas are favorable and how these use cases change in the future. Furthermore, we wanted to know the interviewees' assessments with regard to these future developments. When participants mentioned certain issues, barriers for adoption or concerns with regard to AR, we followed up on statements and investigated different dimensions of the statements in an explorative manner. The highly flexible approach with respect to the interview guide allowed for this procedure. Consequently, our questions were more guided during the last interviews when we focused on assessing whether our categories are saturated and whether they were covering the relevant sub-dimensions.

3.2 Data Collection Procedure

The requirements for including participants in the sample are the following. As the AR technology constitutes a new concept that is hard to compare with prior user experiences, the most important aspect for the initial sampling is that participants could answer certain questions correctly and, by that, showed either a certain degree of knowledge or actual experience with AR. Thus, we distributed questionnaires to potential interviewees to test this knowledge. We included interviewees in the sample when we could observe that this knowledge was sufficient. One of the interviewees is an expert in the field of AR with long-term experience in the field (interviewee 3).
After we conducted the first interview, the audio file was immediately transcribed and coded, and memos are written to reflect the discovered patterns and processes. Consequently, more data is gathered which focuses on the identified categories and their properties. This strategy is called theoretical sampling. Theoretical sampling aims to define the categories and their properties [23]. Our initial interviews include participants who exhibit diverse characteristics, including variation in age, gender, jobs, and distinct relations to AR, which we tested in the preliminary questionnaire. Our aim was not to create a sample that represents society, but to increase the potential variation within the data. We selected the participants according to two different strategies. The first strategy is to elaborate the new properties and dimensions of existing concepts based on participants who are similar to earlier interviewees (minimal comparison). The second strategy addresses the development of new categories and properties based on interviewees with different attributes (maximal comparison). The resulting categories, which are successively differentiated and enriched, thus control the further sampling process. The sampling process can stop when no new categories arise and the

properties of the identified categories are saturated. Saturated categories imply that gathering new similar and contrasting data does not lead to any new findings. Therefore, sample size is not the most important criterion when conducting a grounded theory research. For example, Bowen [25] states that a sample of 10 interviews done by a skilled interviewer could lead to more powerful insights than 50 interviews done by a novice. In this study, we conducted new interviews until no new categories or properties of categories emerged. This process led to a total of twelve analyzed interviews with a minimum length of 42 minutes up to 56 minutes (cf. Table 1).

Table 1. Demographics of the Interviewees

Interviewee	*Age*	*Gender*	*Education*	*Sector*
1	25-29	male	Bachelor	Consulting
2	30-34	male	Diploma	Consulting
3	45-49	male	Master	AR Industry
4	20-24	male	A Levels	Logistics
5	20-24	male	A Levels	Technical Services
6	25-29	male	Bachelor	Car Engineering
7	50-54	male	Diploma	Teaching
8	25-29	female	Bachelor	Information Mgt.
9	30-34	male	Master	Machine Construction
10	15-19	female	A Levels	Industrial Engineering
11	25-29	female	A Levels	Law
12	25-29	female	Bachelor	Managerial Economics

3.3 Initial and Focused Coding

In order to gain insights, to raise the analytical level of these insights and to construct theory from the gathered data, it is important to stop and analyze what has been found during the interviews. Analytic questions are asked to direct and further shape the following data gathering and to structure the data in a way that enables constructing theory. This step is called coding: Pieces of data are labeled to summarize and categorize the available data. Coding provides a tool to sort, structure and analyze a huge amount of data. For coding the data, we used the software package MAXQDA12. Grounded theory uses at least two phases for the data analysis, namely initial coding, in which the gathered data is analyzed line-by-line and segment-by-segment (initial codes fits the data closely); and focused coding, in which the most important and recurring initial codes are structured, integrated and arranged to gain analytical in-depth insights [23]. We used the most frequent initial codes that appear promising to reveal insights about concerns as focused codes. Where it was possible and provided analytic value, we aggregated different initial codes into a focused code that has a broader and more abstract view on the actions and their underlying patterns. After we defined a focused code, we compared it with previous and additional data to refine this code and to identify properties that can provide more insight.

3.4 Memo-Writing, Generation of Categories and Integration of Results

By applying the coding techniques, the data reveals certain structures and details. However, a link between the analysis of data in the coding phase and the creation of a theory or rich description that underlies the actions that have been identified remains absent. Memo-writing provides this intermediate tool and builds the bridge between the collection of data and a potential theory [23]. We used memos to summarize the statements of the interviewees, compare the statements made by participants to other statements in the same and prior interviews, structure patterns and processes of multiple interviews and to raise focused codes to conceptual categories.
The identified categories are the different dimensions of concerns. They represent the highest abstraction level of our analysis. They are defined by the mostly named codes which form the different sub-dimensions of this category (cf. Figure 1). As described earlier, these codes are closely linked to the data.

4 Results

An overview of the results is presented in Figure 1. The figure illustrates the abstraction process that emerged from applying the method described in the previous section. Categories represent the highest level of abstraction. We find that there are four dimensions of concerns of individuals with regard to AR technologies, which constitute the categories in our results. The dimensions are concerns about social consequences due to the use of AR, concerns about privacy, security and concerns about the missing added value AR might generate for the users. Figure 1 also shows the number of initial codes which form a sub-dimension (first number in parentheses). In addition, the second number shows how many different interviewees mentioned these codes. We will discuss each of the category in this chapter in more detail and provide exemplary statements from the interviews in Table 2.

4.1 Concerns about Social Consequences

This category is one of the most complex concepts due to the nature of AR, especially when considering HMDs. The first sub-dimension is the ***potential misuse of AR*** technologies. This focused code is closely linked to privacy concerns, but still different. The interviewees are not only concerned about the increasing possibility to gather data through the high pervasiveness of AR devices, but also about the potential consequences in their social life like a job loss. It is striking that the big benefits of AR, like constant analyses of the real environment, basically cause the concern about misuse scenarios. A strong ***involuntary exposure to ads ("Receiving Ads involuntarily")*** through AR devices is mentioned regularly amongst the interviewees. This concern is specific for HMDs considering the statement of interviewee 4. The other interviewees stated similar concerns about a constant flow of influencing advertisements. Considering the current state of internet marketing with an already high degree of ad exposure, it will be interesting to see how the relevant AR platform or device providers for HMDs deal with this situation.

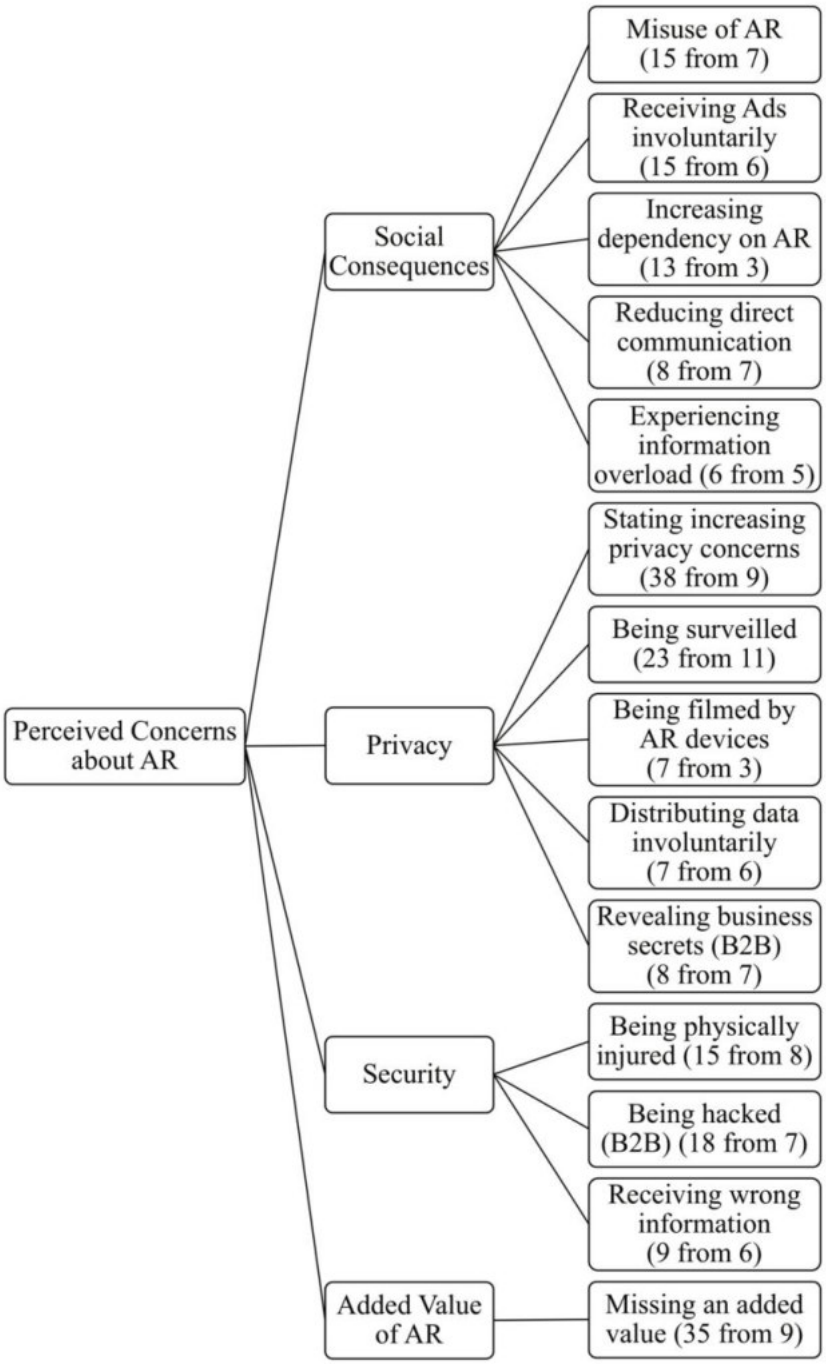

Figure 1. Results of the qualitative analysis process. The parentheses show the number of initial codes from different interviewees (e.g. the sub-dimension "being surveilled" is formed by 23 different initial codes, mentioned by eleven different interviewees)

It is promising to think about that form of advertisement from an economic point of view since users can be confronted with ads at the right place at the right time [26]. The third sub-dimension is about the ***increasing dependency on AR***. Our analysis reveals that the interviewees oftentimes refer to the smartphone when making certain judgements. Here, the exemplary statement also shows this comparison. Interviewee 7 sees a problem in a technology-dependent individual. For AR these concerns are apparently worse than for the smartphone. The next sub-dimension is related to the previous one. It emerges out of several interviewees saying that AR is most likely to ***reduce personal communication ("Reducing direct communication")*** amongst individuals even more than it happens already with the smartphone. This sub-dimension as well as the previous one are difficult to influence by AR developers or managers since they are problems inherent to several forms of AR devices like HMDs. The last sub-dimension is about concerns about ***experiencing an information overload*** when using AR. Information overload is a well-known problem in the digital sphere [27], encapsulated by the quote of Nobel laureate Herbert Simon when he said that "[...] a wealth of information creates of poverty of attention". Our analysis shows that individuals are rather not concerned about the sheer amount of data that is shown to them, but rather about the quality of information. Too much ”bad” information causes an information overflow since it is hard to differentiate which information is useful and which is not. This concern can be addressed by a well thought out information supply. Lastly, concerns about wearing HMDs in the social environment are not prevalent in this analysis. This is interesting since the media reported about incidents where people with the Google Glass were attacked by other people in their environment [28].

4.2 Concerns about Privacy

The literature provides several definitions of privacy and it can be said that Privacy is a concept in disarray. Nobody can articulate what it means [29]. In the context of this paper, a useful privacy definition is the one by Culnan, who states that privacy is the ability of an individual to control the access others have to personal information [30]. Our analysis of the privacy concerns matches the importance of control over personal information for individuals for several dimensions. The category privacy concerns is mainly about five sub-dimensions of concerns. First, interviewees perceive ***increasing concerns due to AR compared previous technologies*** like the smartphone. As interviewee 10 points out, this is mainly due to the perception that AR captures a larger amount and diversity of data. Closely linked to this, is the fear of ***being surveilled*** by government or other able parties. In contrast to this perspective, we find that interviewees also express concerns about the case where individuals ***being filmed*** (as bystanders) by an AR device worn by someone else. The next sub-dimension is about the ***involuntary data distribution ("Distributing data involuntarily")*** due to using AR. Besides following the prevalent law of the country, AR companies should provide transparency to show people what is being filmed, analyzed and stored to overcome these concerns. The last sub-dimension shows a different perspective by clearly focusing on business secrets. ***Being able to keep company information safe ("Revealing business secrets (B2B)")*** is apparently a prerequisite for a wide adoption

of AR technologies in the business environment and need to be considered carefully when designing AR software and hardware.

4.3 Concerns about Security

Our analysis shows that security concerns can be divided into some kind of safety concerns, concerns about getting hacked (mainly mentioned in the B2B context) and concerns about receiving wrong information in the devices. Concerns about ***physical injuries ("Being physically injured")*** also came up in research articles and the press during first months after the appearance of Pokémon Go [31]. In our sample, interviewee 3 mentions potential long-term eye injuries due to the used technology. ***Concerns about hacks ("Being hacked (B2B)")*** are immanent when discussing security. The same holds for the possibility of ***receiving wrong information***. This is possible through malfunctions in the corresponding systems which can possibly lead to damaging exertions of influence.

4.4 Concerns about the Added Value of AR

The last category about the added value of using AR is not as fine-grained as the others. The only focused code we could identify is ***"missing an added value"***. However, it is a reoccurring theme across the interviewees that AR currently provides not enough added value because the technology is not mature enough. This evaluation of the interviewees is shared amongst several experts in the field of new technologies and AR. For example, Tim Cook, CEO of Apple, stated that "AR is going to take a while, because there are some really hard technology challenges there. But it will happen, it will happen in a big way, and we will wonder when it does, how we ever lived without it. Like we wonder how we lived without our phone today" [6]. Our results combined with such evaluations show that AR (especially in the form of HMDs) certainly needs more time and technical maturity to become a technology that is accepted in the end consumer market. In addition, the importance of showing a clear benefit of a certain AR technology to the customer has to be considered. Especially many mobile AR applications are rather designed to show the new possibilities of overlaying information over the real environment. However, only few of them provide a level of utility high enough in the users' daily lives so that they could represent more than just a shenanigan to once use for a few hours.

Table 2. Exemplary Quotes for the Sub-Dimensions from the Interviewees

Sub-Dimensions	Exemplary Statements
Misuse of AR (Section 4.1)	*And that [the data gathered through AR devices] could eventually be used against me sometime. If I say, I worked for my job. But then I was somewhere else and I used augmented reality to look something up, then it could actually be somehow used against me.* (interview 8) *Yes, so it could be [...] that my video recordings or my audio recordings or my behavior in principle by the use of augmented reality gets unlocked*

	for individuals or companies, where I usually do not really want, that they get this data. Be it any advertisers who use this data to send me personalized advertising or insurance, for example, who knows if I drive a little bit too fast in my car now and the augmented reality glasses will pass this data on to my insurer, who will then think about whether or not he will charge me the more expensive premium. (interview 1)
Receiving Ads involuntarily (Section 4.1)	*I would not want to be penetrated every day with any ads that I have to see. I mean, by that, I'm also influenced. That means, that the consumer is permanently influenced in the end.* (interview 4) *So that it now collects data about me, for example, what kind of clothes I normally wear, and when I walk past C&A, it then sends the data to me ah here you like to wear jeans or shirts and we just have shirts here on sale or something. So that would be where I would say, I do not want to see any ads unless I want them explicitly, but I cannot imagine that for my case.* (interview 2)
Increasing dependency on AR (Section 4.1)	*[...] the same positive and negative effects that had the smartphone, only reinforced. Even less self-responsibility, even more is transmitted, even more is automated, even less thinking [required by the individuals] in the negative sense.* (interview 7) *That somehow this [AR] manages this balancing act to have a noticeable advantage for me without that I feel so dependent on it.* (interview 8)
Reducing direct communication (Section 4.1)	*With them [smartphones] the social problems have increased. Social contacts are focusing a lot on the digital world and that social life, which normally exists, has already declined to a certain extent. And I also think Augmented Reality will reinforce that because it's not really necessary to meet friends, if you can see them in a live broadcast over the glasses, or yes, you can communicate directly via all possible communication media. And also has the feeling that you are sitting directly opposite a person.* (interview 12) *So everything that makes everyday life easier, you can clearly assume that that the society is getting lazy, more and more cumbersome. You can already see that. Um less communicates with each other, but more relies on devices. This is increasingly becoming a problem. So, you rely more and more on mechanics, more and more on technology and um, the trend is likely to continue.* (interview 4)
Experiencing information overload (Section 4.1)	*On the one hand, the data must come in smoothly, there must be no great delays, the data must be adapted, there must not be a flood of information, which is useless.* (interview 7) *Simple, that so to speak, that the reality gets into the background and just this information, this added information umm gets the upper hand and uh distracts you from possible events.* (interview 1)
Stating increasing privacy	*Now many see privacy as their private messages or at home private rooms, and through augmented reality you would be potentially recorded in these private rooms. And then perhaps, privacy is defined only for individual rooms, individual conversations or one has to say, that one is*

concerns (Section 4.2)	*private, if no one wears these glasses or so. Because I think that one already gives up parts of his privacy for it. Not that it might be unintentional or something, because we also use cell phones in our private rooms, but I think you could intervene in a different way [with AR devices]. Yes.* (interview 10) *And if you are in some kind of private sphere where you do not want visual or auditory information to leak out. I would probably still resign from it [using AR technologies] in this area until I am really sure that there prevails a sufficient privacy protection.* (interview 9)
Being surveilled (Section 4.2)	*[...] but most devices film the environment all the time, which is usually not recognizable for the surrounding people. And because of that, it would theoretically be possible to gather all the data and make a large-scale surveillance possible.* (interview 6) *Although we already have a lot of camera surveillance, you would also appear in the data of other people. So, by the fact that everyone could be monitored by anyone or just filmed.* (interview 10)
Being filmed by AR devices (Section 4.2)	*[...] if the technology would come to use in everyday life and [...] video material, for example, from different people walking around would be collected, then this would of course limit the privacy of the people according to current law* (interview 1) *For example, in my home I would not want a camera to permanently record my, yes my, apartment or my surroundings. My yes, my living situation or even if I am in the bathroom or something similar, that I am permanently filmed there.* (interview 12)
Distributing data involuntarily (Section 4.2)	*[...] what is recorded, is it recorded at all, how is it processed, where is it stored. I think that would be all the questions I would ask myself if I have such a device in my hand, because I'm very interested in the question, who can still see what I see?* (interview 5) *[...] I will probably never be able to control what it [the AR device] transmits, that is, which areas of my field of vision and whether it cuts out certain areas of my visual field so that people I see are not transmitted. I do not think we will have such options for an end user device. Basically, I would like to have a variety of granular options, for example, I want to say, I do not want data about other people to be transmitted or I do not want conversations with other people to be shared.* (interview 7)
Revealing business secrets (B2B) (Section 4.2)	*[...] um, because that's what the company lives on, that it's the only one who knows this information. That's why the problem is that you give the augmented reality application information so that it can process them furthermore, but this information must not be allowed to go outside. That's why I think companies need to establish a specific regulation where augmented reality can and cannot be used.* (interview 11)
Being physically injured (Section 4.3)	*Of course, there is much discussion with the glasses. What impact will this have on the eyes in the future? Umhm, above all new topics like light field technology, projections in the eyes and so on. Does it leave any damage in the long term?* (interview 3)

	There were also some cases in which you were so deepened in that [MAR applications] so you may also provoke accidents in the real world, because you do not see, for example, a lamp post, because somehow it is covered by other things. (interview 10)
Being hacked (B2B) (Section 4.3)	*Um, like all technical devices or even software, it is of course hackable, vulnerable.* (interview 2) *But in itself we would have the same concerns [as for smartphone and laptop use and storing data in data clouds] that our data could be passed on to third parties or these glasses could be hacked and this is currently also the case.* (interview 10)
Receiving wrong information (Section 4.3)	*[...] a set of algorithms behind it that can make mistakes, have wrong data, or possibly deliberately push in the wrong direction in the sense of propaganda. This is of course also possible if you are now really sitting at a data source and a large part of the people uses data similar to Google. That you can put your political mark on it, too.* (interview 7) *[...] gaps or IT-security deficits can be exploited very quickly and I think, examples would be the insertion of false information [...]* (interview 5)
Missing an added value (Section 4.4)	*So, if I refer it to myself now, [...] I think, as I said earlier, that it is not mature enough at the moment to really bring much benefit to me or change or facilitate my life drastically now, or so.* (interview 11) *[...] and above all, the question is what does it really bring me now? So, does it make sense now to buy a license for one hundred thousand euros to save a [previously used] device, but in the end it [AR glasses] shows me exactly the same information, but in a different form.* (interview 2)

5 Discussion

Our analysis provides a rich description of the different concerns expressed by the interviewees. We find that the main dimensions are concerns about social consequences, privacy, security and the missing added value through using AR. The results have practical implications for hardware and software developers as well as managers in AR companies with respect to specific design decisions that may weaken these concerns and foster future market adoption. As an example, our results indicate that the application of AR in the B2B context has to be accompanied with a well-thought policy on where the technology is allowed to be used and where it is forbidden. In the B2C context, AR products should be specified in a transparent way with respect to data gathering and processing. Furthermore, our research confirms the problem of the privacy of bystanders of AR users which is also found in the literature [32, 33]. Researchers, practitioners and governments have to find solutions to deal with this kind problem affecting the public sphere.

We contribute to the literature twofold. First, in contrast to the majority of earlier work on AR, we do not focus on technical issues of the technology, but solely on perceptions and concerns of potential users of it. Second, we show that individuals associate multi-faceted concerns with AR. These concerns are partially comparable to related findings

about concerns with respect to smartphones. However, several sub-dimensions show AR-specific issues which have to be considered and investigated by researchers in order to overcome the concerns of potential users.

Since we applied the constructivist grounded theory approach by Charmaz [3], certain limitations arise. The method assumes a mutual construction of the reality by the researcher and the interviewee and it considers the researchers experience and view on reality. On the one hand, we choose the constructivist approach on purpose, because it supports our underpinnings and view on the world. On the other hand, we aim to minimize the personal influences on data collection to base our analysis in as much data as possible. However, our findings represent one possible version of the results which we analyzed based on our interactions with participants and the data. In addition, we did not set out to develop a model of how these concerns interrelate with each other and affect other variables like attitudes towards AR. Thus, this work only provides a rich description of the concerns related to AR as a first step to understand the perceptions of users in more detail.

Future work can build on our results to further investigate the most important concerns associated with AR technologies. A next logical step would be an extensive quantitative analysis of the influence of the different categories and dimensions of concerns on the intention to use AR, and if possible, on the actual use behavior. In addition, we could show that a qualitative approach is very useful for investigating innovative technologies like AR since most of the individuals are highly heterogenous with respect to their knowledge, perceptions and attitudes towards new technologies like AR. Thus, we recommend researchers to consider qualitative research methodologies for future user studies and evaluations to gain deeper insights into the users' perceptions and attitudes.

6 Conclusion

In this article, we identified four major categories of concerns about AR technologies. For every category, we disentangled the different sub-dimensions (if existent) and partly provided suggestions for how to deal with these concerns in order to increase the possibility of successful market entries of AR technologies in the future. Our analysis focused on AR technology in general and is therefore a first step towards a more granular understanding of concerns. Thus, the specific concerns can be more or less pronounced when looking at the specific type of AR technology. In addition, some of the sub-dimensions are not directly addressable by developers or managers (e.g. concerns about reducing direct communication or increasing dependency on AR) since they are, although very important, rather an object of a philosophical discourse that has to be conducted in the society itself.

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