Co-Speculating on Dark Scenarios and Unintended Consequences of a Ubiquitous(ly) Augmented Reality

Chloe Eghtebas
Technical University of Munich
Germany
eghtebas@cit.tum.de

Gudrun Klinker
Technical University of Munich
Germany
klinker@cit.tum.de

Susanne Boll
University of Oldenburg
Germany
susanne.boll@uol.de

Marion Koelle
OFFIS - Institute for Information Technology
Germany
marion.koelle@offis.de

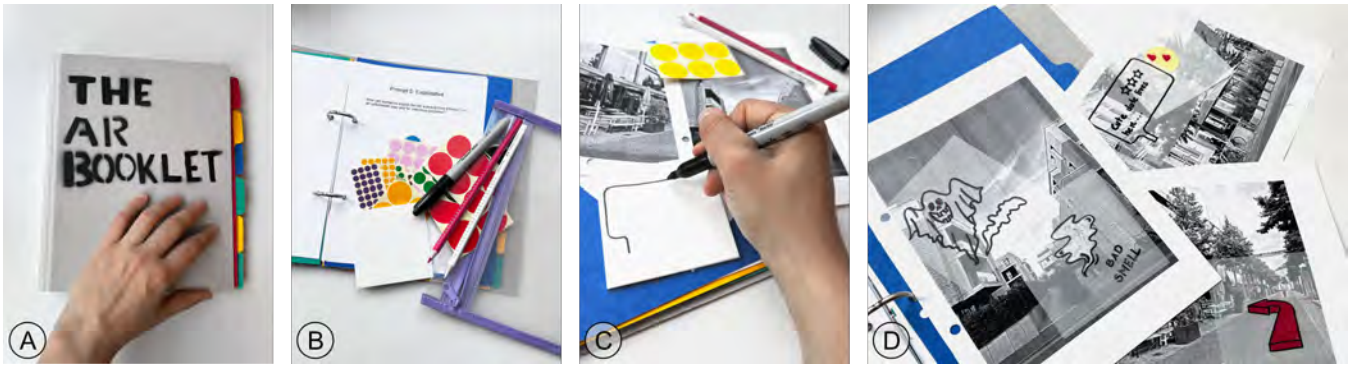

Figure 1: Making use of design workbooks (A) customized with photographs taken by 12 globally dispersed participants and their immediate surroundings, we co-speculate on future Ubiquitous Augmented Reality (UAR). Participants added augmentations to the photographs using craft materials (B), and sketched annotations (C). Their ideas articulate a diverse range of potential 'dark' UAR scenarios (D) reflecting their unique backgrounds and lived experiences.

ABSTRACT

The vision of a 'metaverse' may soon bring a ubiquitous(ly) Augmented Reality (UAR) delivering context-aware, geo-located, and continuous blends of real and virtual elements into reach. This paper draws on speculative design to explore, question, and problematize consequences of AR becoming pervasive. Elaborating on Desjardin et al.'s bespoke booklets, we co-speculate together with 12 globally dispersed participants. Each participant received a custom-made design workbook containing pictures of their immediate surroundings, which they elaborated on in situated brainstorming activities. We present an integration of their speculative ideas and lived experiences in 3 overarching themes from which 7 'dark' scenarios caused by UAR were formed. The Scenarios are indicative of deceptive design patterns that can (and likely will be) devised to misuse UAR, and anti-patterns that could cause unintended consequences. These contributions enable the timely discussion of potential antidotes and to which extent they can mitigate imminent harms of UAR.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous computing**.

KEYWORDS

Dark patterns, anti-patterns, speculative design, future technologies

ACM Reference Format:
Chloe Eghtebas, Gudrun Klinker, Susanne Boll, and Marion Koelle. 2023. Co-Speculating on Dark Scenarios and Unintended Consequences of a Ubiquitous(ly) Augmented Reality. In *Designing Interactive Systems Conference (DIS '23), July 10–14, 2023, Pittsburgh, PA, USA.* ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3563657.3596073

1 INTRODUCTION

Augmented Reality (AR) has developed over the last decades, from early prototypes demonstrating its feasibility and opportunities into a technology than can be deeply used and embedded into our daily practices. From games, to navigation, and retail - AR is being adopted everywhere, with a stream of new devices on the market to support AR. Today's AR systems already possess the potential to

DIS '23, July 10–14, 2023, Pittsburgh, PA, USA

ACM ISBN 978-1-4503-9893-0/23/07…$15.00
https://doi.org/10.1145/3563657.3596073

be context-aware, geo-located, and to deliver continuous, and thus ubiquitous (pervasive) AR overlays [40]. With its connection to the physical objects located in the real world, augmented reality offers not only great opportunities for living in a digitally augmented real world, but also comes with unintended consequences.

Through increasing commercial interest rolling-out large-scale, networked AR (and VR) platforms, social connection, social and societal risks of Ubiquitous Augmented Reality (UAR) move into focus. Evidently, UAR will face similar risks and challenges previously observed in social media: bullying individuals, distributing false information, influencing public opinion and more [44]. Prior work indicates that AR, being *in real-time* as well as *situated* while *blending real and virtual* (cf., Azuma's well-known definition [7]), may exacerbate existing challenges and evoke new risks. Yet, the extent and diversity of prospective 'dark' scenarios and unintended negative consequences has so-far not been mapped out, which limits the development of countermeasures or 'antidotes'.

This work articulates potential *deceptive design patterns* [15], a.k.a. dark patterns, as scenarios in which UAR can be (and likely will be) abused, and *anti-patterns*, as scenarios in which UAR may cause unintended negative side effects. We argue that mapping out the space of potential risks and challenges at this point in time is crucial, as deceptive designs patterns, once widely practiced, are more difficult to dispel. A contemporary example of this can be seen by the GDPR to stop privacy invasive tracking across websites, whose regulatory counter measures work with questionable efficacy [65]. Similarly, decisions taken in technology design, specifically the design of UAR, will from this point onward have potential social, political, and environmental impacts.

We chose *co-speculation* as an approach to investigate the question: *What deceptive design patterns and anti-patterns may arise from a ubiquitously Augmented Reality?* Speculative approaches have been popularized in HCI as they allow to explore emerging 'upstream' technology [20, 55, 81]. Co-speculation is a design research method which extends these approaches by involving participants in shared speculations [25, 26, 48, 83]. Inviting participants 'who are well positioned to actively and knowingly speculate with us' [83] allows to include relational and situated ways of knowing what, we as authors, otherwise would not have access to: our participants' unique backgrounds which draw their attention to particular aspects of the world that may provide 'hooks' for deceptive design patterns, or afford anti-patterns that would otherwise be missed.

In this work, we present results from a multi-step investigation inspired by Desjardin's *Bespoke Booklets* [25]: we assembled photographs that in total N=12 geographically dispersed participants took in their usual surroundings (e.g., their neighborhood) into a personalized, physical workbook each. The workbooks were shipped for on-site speculation and context-specific brainstorming to the participants who documented their ideas of dark scenarios by sketching, adding stickers, labels or textual explanations. Co-speculation was continued during an exit interview. Subsequently, we perform a Thematic Analysis [14] of the scenarios devised by the participants, and the participants' elaborations during an exit interview. We systematize and elaborate potential dark and unintended consequences of UAR, which we present in 7 scenarios that relate to 3 overarching themes and supplement with a discussion of antidotes, which we understand as architecting technical design decisions. We also critically reflect on the applicability and limitations of antidotes and resulting implications.

Our work presents the collected speculative ideas and lived experience of participants deceptive designs in UAR in 3 overarching themes. Our work also contributes 7 dark scenarios, resulting from further analysis of the themes, as a way of providing literature-based description and insight into what potential deceptive design patterns, or possible pitfalls (anti-patterns), might, or likely will, be created in the emergence of UAR. Finally, we follow up with a discussion of dark scenarios with technological solutions, or 'antidotes', that are opportunities to mitigate a dystopian UAR and conclude with to what extent technical antidotes can effectively prevent the potential issues caused.

2 RELATED WORK

We situate our work by defining Ubiquituous Augmented Reality and by looking into existing work on deceptive designs, dark patterns, and anti-patterns.

2.1 Ubiquitous Augmented Reality

Ubiquitous Augmented Reality (UAR), a term composed from *Ubiquitous Computing* [85] and *Augmented Reality* (AR) [7], describes a version of AR that can be used continuously (i.e., anytime, anywhere) and adds digital, real-time augmentations to the physical environment to create context-aware pervasive AR experiences [40]. UAR exceeds the capabilities of early AR applications, where digital information is simply rendered on top of a marker, e.g., on top of a magazine cover [89], but rather as it is thought of to be more tightly integrated with larger contexts, e.g., urban environments. Part of this vision has already been realized as mobile AR, for instance augmenting a city's skyline with location-dependent information [30]. Previous work has further aimed to make AR systems contextually aware by situating information stemming from websearch [50] or social media [28, 52]. This data is then tied to a location to aid the accessibility of relevant information on-site. Further perspectives are brought in by 'Diminished Reality', where an AR system modifies a physical scene by 'diminishing' physical objects, either by removing them entirely or by changing their appearance in real-time [46, 62]. In the future, we expect AR systems to become increasingly capable and, fueled by technological breakthroughs, pervasive, and immersive. This blending of real and virtual has already been seen to intensify feelings of loosing agency over one's open perception, especially when perception is mediated in a subtractive or destructive manner [41]. This motivates our present work to anticipate potential misuse of UAR, through its ability to have disempowering effects on users, but also likely, bystanders.

2.2 Deceptive Design & Anti-Patterns

Dark patterns, commonly encountered in the form of website or mobile interfaces that are intentionally designed to trick or persuade the user, are an interaction design paradigm that works against the users interests [3]. Prior work has analyzed existing deceptive design patterns in various areas, including website, game, and interaction design [37, 57]. Recently, there has been a community-wide shift to use the term deceptive design patterns, in place of dark

patterns, in support of inclusivity [15, 66]. Deceptive designs can cause various harms like tracking personal information, diverting one's attention, spending time, and be financially draining, because of the psychological mechanisms used to design them [12]. Even when their mechanisms are known, they can still cause harm to those who encounter them [11]. In contrast, designs that are well-intentioned, but still deceive the user by unknowingly embedding deceptive designs or unintentionally cause negative consequences, typically referred to as *anti-patterns*. Anti-patterns are a term first coined by Andrew Koenig, as a response to object-oriented pattern designs that seemingly solved issues in software engineering, but still result in consequential side effects [16, 49].

Context awareness of UAR creates more direct access to localized personal information. This can enable new types of inferences [71], as UAR will rely on some type of location-based information to function. Most closely related to our work, Greenberg et al. [38] have sketched out deceptive design patterns of proxemic interactions. They note how bystanders opt-in 'simply by entering a space' – a problematic effect that likely extends towards UAR. Yet, the extent to which UAR fuels deceptive designs patterns and anti-patterns is so-far unexplored. Particularly, AR-specific characteristics (not shared with public displays acting on proxemics) have not been discussed. These include the asymmetrical nature of AR displays, where the augmented overlay is only visible to the user, while their interactions within the physical surroundings remain observable (e.g., to bystanders). With this work we contribute a first critical discussion of UAR in the context of deceptive, 'dark' designs[1].

3 METHOD: CO-SPECULATING ON UBIQUITOUS AR

Novel perspectives often emerge slowly over time and may originate from multiple provisional ideas. Hence, we decided against more researcher-led, and theory-driven approaches and in favor of co-speculatively developing ideas over an extended time frame of several weeks with participants from outside our research context. This allowed us to diversify perspectives and to elicit a broad set of plausible dark scenarios and their possible consequences.

Our approach draws inspiration from several design methods: our procedure, materials and tasks are closely related to *investigative probes* [10, 33, 43]. Probes have become a popular, design-oriented means of discovery in HCI. A typical goal of probes is to provoke inspirational responses from participants who are invited to complete, iterate and reflect on materials and instructions provided by the researchers. They are well-suited for collecting reflections remotely and over a period of time. Our work further builds upon *co-design*, in the sense of *co-speculation* about possible futures [29, 83].

In our study, we invited the participants to become co-designers by literally sketching out dark scenarios in a booklet or 'workbook'. *Design workbooks* are an established research technique, where several closely related design proposals are curated to elicit feedback, reflections, and to refine a design space [9, 19, 34, 87]. For our study, we created a personalized workbook for each participant, taking inspiration from Desjardins et al's *bespoke booklets* [25, 26]: using photographs that the participants took in their usual surroundings (e.g., their neighborhood) as basis for co-speculation facilitated our participants' situated and context-specific brainstorming.

[1]For the lack of a (better) alternative, we used the term 'dark' in this work to refer to scenarios that foster deceptive design, misuse or create unintentional negative consequences.

3.1 Participants

We recruited our participants through connections of personal contacts through word-of-mouth, flyers, and snowball sampling [51]. We carefully aimed for a culturally diverse, and geographically dispersed set of participants as their unique backgrounds and niche differences in environment could lead to a wider span of collected ideas, thus fuller collection of potential speculative misuses. In addition, following common recruitment criteria for diary studies (e.g., motivation, technological aptitude) [2, 51], we aimed to select participants that were comfortable with the task, and had the possibility to follow through with the study over several weeks. The latter was crucial due to the multi-stage method involving personalized workbooks and to allow for ideas to evolve over time. Of a total 19 recruited participants, 12 completed all phases of our study. The 12 participants who completed the study were between 21 and 37 years old (M=28, SD=4.5). Below, we provide relevant details on their backgrounds (e.g., attitude towards social media, privacy, etc.) to give a better sense of how their lived experiences shape their brainstormed ideas and suggestions. We redacted elements (e.g., city names) that may compromise the participants' anonymity. Names are alphabetically unique aliases assigned to each participant.

Alex (F, 32) lives in urban Scotland and maintains a travel blog. She likes to share her travel experiences, especially photography, publicly online. Yet, she is concerned about privacy, which is why she carefully curates and redacts each of her posts.

Brent (M, 35) lives in suburban Germany and works as a Software Engineer. He is very enthusiastic of what future technology could bring. He makes use of social media for staying in touch with close friends and haphazardly uses dating apps.

Emily (F, 26) is a globetrotter from Hong Kong, currently living in urban Portugal. Working in regenerative agriculture, she moves frequently, staying in touch with friends via social media.

George (M, 30) lives in urban India and works as a media director and artist. He creates thought-provoking art exhibitions which he likes promoting online. He limits his intake of social media as he is critical on its effect on mental health and well-being.

Henry (M, 21) is a Forestry Technician in rural Germany. When online, he interacts with only a few social media groups that are thematically focused. These groups are subject to uninvited harassment from outside groups with strong political agendas.

Illana (F, 24) is finishing her Masters in urban Japan. She likes sharing her art and photography work online. She is originally from Hong Kong and stays in touch with friends and family via social media and has experienced heart break through chatting apps.

Jack (M, 28) works as a lawyer in urban Germany and is a tech enthusiast. Yet, he is highly skeptical when it comes to social media, as he is concerned about its negative effects on society.

Mindy (F, 37) lives in urban Mexico. Currently, she is a housewife. In her social media networks, she encounters heated debates regarding her community and greater social issues.

Nicole (F, 28) is an English teacher from the US, who is currently living abroad in urban Germany. She likes to stay in touch with friends and family back home but she perceives social media as potentially dangerous, as she has had prior negative experiences with what she calls "creepers".

Penny (F, 24) works as a product manager and lives in urban US. She is a socialite and theater productions are her big hobby. She uses social media to advertise the plays she takes part in. Previously, she uploaded videos where she taught language online, and encountered inappropriate comments.

Quin (F, 26) is originally from Europe but has been living in urban Japan completing her Masters in Media Design. She uses social media but is cautious as she had some negative experience being bullied online back in high school.

Stacy (F, 29) lives in urban China and works as a designer. In her work she creates virtual avatars. She uses social media but is sometimes frustrated by the sad stories she encounters online.

3.2 Procedure & Task

Our study procedure was structured into four phases: Opening Interview, Photo Collection, Situated Brainstorming, and Exit Interview in total of which extended anywhere between 2 and 6 months. Additionally, we explain the photo collection and brainstorming prompts in the sections below:

Opening Interviews (Phase 1). First, we ran *one-on-one introductory sessions and opening interviews* where the participants were introduced to the topic, procedure, and tasks. The introductory session (via Zoom) included a brief presentation on Augmented Reality, where we deliberately opted for a broad definition of AR. We described AR to include 2D/3D augmentations, not necessarily registered in 3D, but spatially located. Spatially tied multi-sensory augmentations, e.g. auditory, haptic, olfactory and taste senses were encouraged to be considered. Although presented with some technical details, participants were told not to think about how the technology behind their ideas or interface design would be feasibly implemented, rather focus on the content and outcomes of augmentations visualized either through handheld, head-worn/body-mounted, or environmentally-projected displays. We furthermore collected informed consent, demographic data and information on the participants' background.

Photo Collection (Phase 2). Second, we collected photos from the participants in order to build their individualized booklets, where the photos served to emulate the types of scenes they might encounter in UAR. We started the *photo collection phase* (average duration of 4 weeks 3 days with a standard deviation of 4 weeks). Participants were instructed to take pictures of their usual surroundings (at home, on their commute, in nearby cafés, etc.). We felt that it was crucial to include this phase as AR is inherently situated in 3D space. By using these photos to tailor each workbook exclusively to participants' surroundings, we aimed to increase their ability to relate to the consequences the situatedness an augmentation may have (e.g., in contrast to information shown in a web browser) as well as to depict diverse scenes matching each participant's locale. During the photo collection phase, participants were emailed five photo prompts over a course of a week or all at once depending on their preference. There were five different prompts to inspire users to take new or upload existing photos they have from their neighborhood, and that are similar to the types of photos they might already upload to social media and that do not have one primary human subject (e.g., selfies).

Photo Prompts. The photo prompts included *Day 1: Curbs, Street Corners, and Perspectives* where participants were to take pictures of impressions of their neighborhood to send to a pen-pal, *Day 2: The Most Beautiful Spot* which showed potential local touristic spots or something that could be shared on Instagram, *Day 3: Urban Legends* where participants were to take photos of local legends or take a photo that could be used to spark one, *Day 4: Mental Notes* where participants took photos of places to remind themselves of unfinished errands or goals, and *Day 5: Nostalgic* where participants took photos of places they remember having a good memory in, or where they would like to hang out with their friends again soon. These prompts were arrived at through the authors brainstorming where they could imagine a prevalence of AR annotations in the wild when social media is blended with UAR. Participants were asked to take pictures of scenes in their neighborhood to have accessibility to visit the location again to facilitate the situated brainstorming. Each participant received a personalized link to a privately hosted cloud folder where they could revisit anytime to upload or delete pictures to complete the first phase.

Situated Brainstorming (Phase 3). Third, we crafted a personalized workbook based on the participants' photographs as a basis for a *situated brainstorming and ideation phase* (average duration of 11 weeks 6 days with a standard deviation of 2 weeks[2]). Creating a physical booklet in a sturdy binding (cf., Figure 2) allowed the participants to take it with them and do the ideation on-site, i.e., where they took their original photos (we called this 'situated brainstorming'). We selected 9 to 18 photographs from the photo collection phase for each participant and printed them in gray-scale and with reduced intensity (to afford sketching overlays) on A5 paper. The photo selection was done by the first and last author on a case-by-case basis, primarily focusing on each photograph's ability to contain augmentations (i.e., we removed extreme close-ups, etc.), increasing the overall diversity of scenes in each workbook (i.e., we removed double or overly similar photos, etc.). We furthermore modified the photographs by removing any identifying information (faces, street or business names, etc.) that would give away the participants' identity, invade other's privacy, and to later display the participants' drawn ideation given their additional consent. Print-outs were filed into a binder, which also included one separator sheet for each task (see below paragraph), along with a pen, red pencil, stickers, and transparent post-it notes as seen in Figure 1. We decided for a binder, as this allowed participants to detach the photographs from the tasks and the workbook was mailed physically to the participants. Participants were free in how they augmented the photographs, including sketching, adding stickers, labels or textual explanations.

Brainstorming Prompts. We conducted four pilot studies with colleagues using pre-selected pictures of our office to test and iterate our brainstorming prompts and see if they sparked the right

[2]Covid-19 impacted the shipping times which are reflected in these numbers.

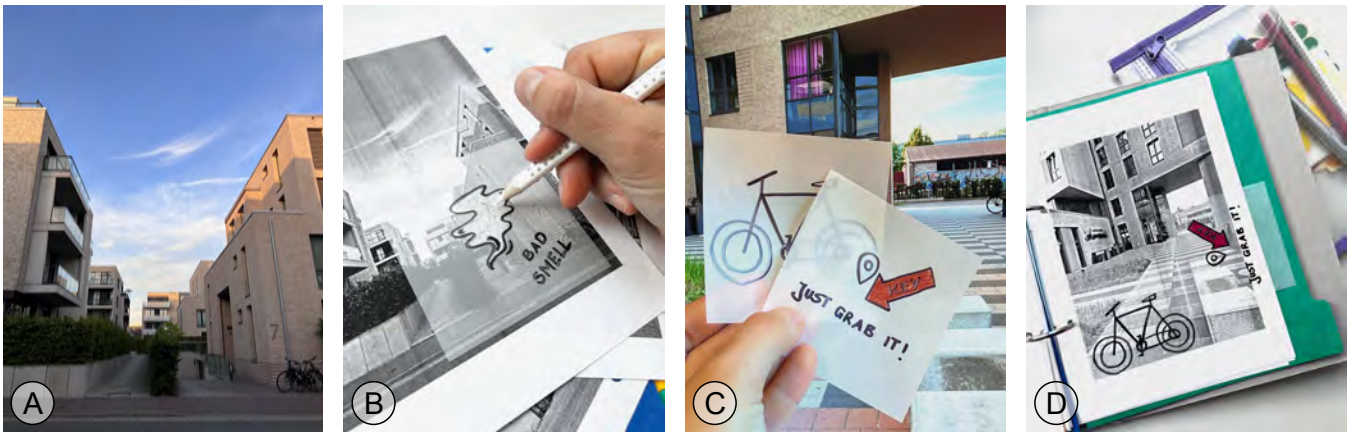

Figure 2: Situated brainstorming with a physical design booklet. We asked our participants to capture photographs of their immediate surroundings (A) and augment them using translucent post-its, sketches and other craft materials (B). Some participants re-visited the location where they took the photograph, (C) sparking additional ideas for their booklet (D).

kind of ideation among participants. Seven prompts were finalized and included in the final booklet sent to participants. *Prompt 0: Icebreaker* created the setting for all other prompts, which was to imagine the type of content if social media posts, futuristic and existing, were augmented onto the streets. From prompt 1 on-wards, we asked participants to ideate harmful augmentations to a photo representing a location of their choosing. For *Prompt 1: Social Media on the Streets* participants were to ideate an augmented harm to a specific person or group, for *Prompt 2: Oversharing*, a harm to the content creator or poster themselves, *Prompt 3: Should have kept to 2D*, how having the augmentation in AR could be more harmful than if it were on social media, *Prompt 4: Over Time*, how AR content can be made more harmful overtime versus in the moment, *Prompt 5: Exploitative*, how AR content can intentionally exploit people. The last prompt, *Prompt 6: Other Ideas*, was an open call for other problematic ideas that might not have fit into the previous prompts.

Exit Interview (Phase 4). Fourth, we invited the participants in another one-on-one session to *explain their ideas, co-speculate further* and to complete a brief *exit interview*. The sessions were loosely structured around the questions: *Which of your entries/ideas do you find most harmful?*, *What sets this harm apart from one on social media?*, and *How could this harm be made multi-modal?* Iterating through ideas, participants were asked to interpret, react, reflect and elaborate upon the ideas they had collected. Sessions were held using video conferencing software (Zoom) and lasted between 23 to 49 minutes.

On study completion, participants received 25 USD (approx. 24 EUR) in appreciation for their time and effort. Out of the 7 participants whose participation was incomplete, three finished the photo prompt stage for which they received 5 USD in compensation. We obtained ethics and data protection approval at Technical University of Munich under application number 338/21 S-KK.

3.3 Positionality Stance & Reflexivity

Just as our participants' ideas are shaped by their unique backgrounds, our interpretations of their proposals in coming up with Chapter 5's Dark Scenarios and Antidotes are shaped by our own prior experiences. Thus, reflexivity, as advocated by Brown and Clarke [13], is essential to achieve research transparency. Here, we reflect on our own backgrounds and individual positioning which influences interpreting, sense-making and theme generation.

The team of authors unites diverse computer science backgrounds at various levels of seniority in their academic careers. All four authors identify as women, have good salaries working in industrialized lives, have traveled outside of, but continuously lived, worked, and studied in Europe and North America in variously sized cities. One of the authors had been a target of online stalking previously which made her delete personal social media accounts. Two of the authors share a strong technology-driven perspective on Augmented and Virtual Reality. Previously, they focused on enabling the use of AR in real-work applications, including issues of usability and practical impact. The other authors' interests lie in empirical and participatory perspectives and social and legal aspects of technology use. This collaboration aims to bring both perspectives together by asking, what solutions (or "antidotes") are technologically feasible, and by critically reflecting to what extent (if at all) we should rely on them. Their individual, personal attitudes towards technology range from extreme tech-enthusiasm towards privacy concerns and skepticism, and all authors share the belief in technology as an empowering tool – if 'done right'.

3.4 Data Collection & Analysis

Participants scanned or photographed the pages of their physical workbooks or mailed them back. Thus, we were able to collect three kinds of data: (1) crafted annotations, (2) the textual explanation (optionally) provided by the participant, (3) additional thoughts and elaborations collected during the exit-interview which were audio-recorded and transcribed.

At first, we analyzed participants' brainstormed data following reflexive thematic analysis (RTA) [14]. We found RTA to be well suited for exploring our participants' ideas, because unlike other qualitative approaches (e.g., qualitative content analysis [58]) it characteristically builds upon the authors' interpretation and sense-making to assign meaning to observations. It is inherently interpretive and reflexive, and well suited to inductively uncover new perspectives and latent meaning.

The initial coding and first analysis of the transcripts was done by the first and last author. After a phase of familiarization, we worked towards themes that would contain one central idea illustrating a plausible scenario where UAR, being present and situated, would lead to dark or unintended consequences. Draft themes were structured, merged or divided throughout the process, e.g., between the first and third phases of analysis, our initial five themes (Anti-examples, Augmented Reality Causes change in Physical Reality, Situatedness of information Promotes Psychological, Physical, Social, or Financial Harms, Augmentations are Misleading, Ubiquitousness of "Touched Up" or Augmented Environments) converged into only three overarching ones (titles of Sec 4.1 to 4.3) which limited the overlap of where our resulting dark scenarios were situated in each theme. Iterations were mostly done by the first author and then reviewed and discussed by the whole research team at regular intervals. In this process, we created a thematic map, drawing connections between individual ideas, codes and themes, using a Miro board[3]. We iterated themes and sub-themes over several months, contextualizing with our own experiences, research questions and prior work. Thus, our analysis, i.e., mutual sense-making based on the collected ideas, may also be understood as the fifth phase in our research procedure.

To this end, our approach also deviates from thematic analysis, as its final result is not (only) an interpretation of our participants' lived and reported experience but rather an elaboration on their imagination. Thus, building upon the analysis of our participants' envisioned risks, and actual concerns, allowed us to broaden our own perspective to systematize and elaborate potential dark scenarios and unintended consequences. Our approach also differs from Desjardin's approach to bespoke booklets [25], which stresses subjectivity over generalization. In contrast, we incorporate the broad and unique perspectives of our participants into joint, more generalized themes and ultimately, dark scenarios. This allowed us to synthesize diverse subjective views into a digestible format, making them accessible for debate and further action.

4 FINDINGS: (UN)INTENDED CONSEQUENCES OF UAR

Our participants produced in total 401 distinct ideas of how UAR might look like, which we analyzed qualitatively using RTA. Due to our ice-breaker (Prompt 1) the ideas brought up by our participants also included several benign, even beautiful scenarios, like a *"praying tree [that] shows audio bubbles of various prayers"* (George). Yet, a total of 291 ideas included explicit or implicit references to potential harms including *physical*, *social*, *financial*, and *psychological* harms and their intended or unintended negative consequences of UAR.

[3]https://miro.com/, accessed 15/09/2022

Throughout our analysis, we focused on ideas with *AR-specific characteristics*, i.e., where AR merges the real and virtual in real-time in 3D, that cause harm, or generate novel, unlooked-for risks and challenges, exacerbating issues known from other, more widespread technologies. Our RTA resulted in three overarching themes, which we describe in the following sections. We dedicate one section to each of the three themes and detail on how they relate to the ideas our participants collected and elaborated on in their booklets and interviews. For illustration, we selectively report how often certain ideas or motives were named by our participants. Yet, we take note that the quantity is not necessarily reflective of a specific motive's potential impact or relevance.

Authors' Note (Trigger Warning): The following sections discuss malicious uses and negative consequences of technology. While we were careful to limit the mention of distasteful or offensive examples to a minimum, some scenarios may be perceived disturbing by some readers, e.g., Chapters 4 and 5 have mentions of suicidal ideation and targeted action towards vulnerable minorities.

4.1 Situatedness of Information Causes New Types of Risks

Characteristically, Augmented Reality embeds digital information three-dimensionally alongside the real environment. In addition to content that is inherently problematic, no matter how it is displayed (e.g., racist or sexist slurs, depictions of violence), AR can cause or accelerate actual harms, even when well-intentioned.

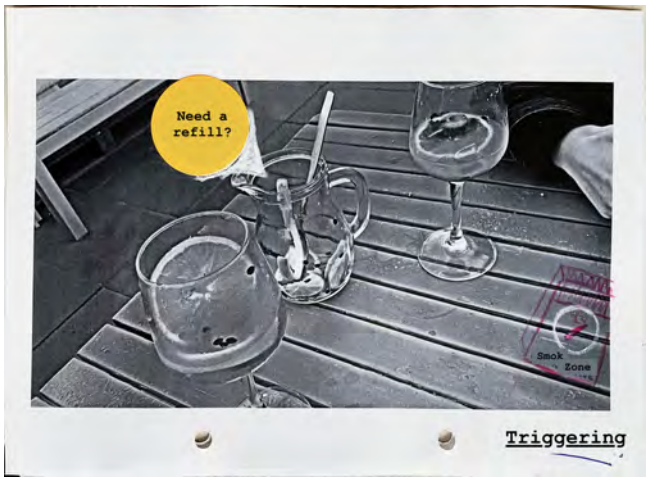

Figure 3: Ideated scenery created by one of the participants. Here, a situated augmentation *"need a refill"* is designed to incite the user to order another drink. Text reproduced for anonymity.

For instance, situated display of information can **manifest real-world changes to a physical location**. Three participants suggested how *"posting a favorite [or] secret spot can cause many visitors"*

(Henry) and consequently cause environmental changes. Unintentional, temporary invasion of crowds may occur at locations that are unprepared and lack the infrastructure for a large volume of visitors, a concern verbalized by Emily: *"[…] too many people, they don't have the infrastructure to have so many people and there could be trash and it could lead to conflict within the communities."* Here, what would be considered a 'large' crowd may be location-dependent: one hundred additional visitors might be inconsequential for a tourist site but a significant disturbance in a backyard. Similarly, five participants envisioned virtual posts to be perceived as 'invitations' for malicious actions. They may promote vandalism *"if you see that in AR, it could maybe trigger someone to target cultural monuments"* (Emily), or unsustainable behavior when viewers consciously or unconsciously comply: *"post saying government can't control you and to take what you want from the ocean"* (Mindy). In both cases, real and severe consequences arise from the virtual element being pinned to the physical.

Situatedness of augmentations can also **trigger rash, ill-considered decisions**, because they co-locate impulse and opportunity. We collected a total of 11 ideas that depicted incentives to attempt dangerous, or otherwise problematic, actions tied to a specific location. Emily suggested: *"dare you to just jump!"* or *"swim out to the furthest rock!"* Yet, such dares do not necessarily have to be intentional. In one of our pilot studies, a participant sketched out a scenario where a usable parabolic slide art installation was augmented with *"It is forbidden to slide with a bobby car!"* – a ban easily mistaken as a challenge (taken up by Scenario 7). Additionally, situated augmentations can be used to trigger vulnerable peoples as illustrated by Emily in Figure 3, targeting those battling alcohol or smoking addictions. Additionally, those *"not protected and are new to the city"*(Quin) could be caught off-guard in being recruited to certain harmful groups or cults as illustrated in Quin's booklet sketch which she further elaborated on during the interview: *"it all started with inspirational quote that would push people to think about their existence …But when it comes to religion, there are so many scams and cults going on, it is perfect timing and they push the buttons that really hurt"* in order to gain new recruits. Lastly, Iliana reflected about the danger of augmented suicide letters left on a bridge and noted *"if there is a lot of people who [commit] suicide [at this bridge], I think their story is really beautiful and somehow I think it is worth to try it because they tried it."*

Our participants reflected on how, in contrast to traditional media, ubiquitous AR **can cause association purely by proximity**, e.g., when content is situated next to a person or object. Maliciously placed augmentations can also be used as a form of gossip with the intention to harm specific persons *"labeling someone or their home falsely as a pedophile or sex offender"* (Mindy). Due to the low cost of attaching labels to a person or their belongings, people can intentionally and unknowingly be taken advantage of without their ability to control such annotations, like in Nichole's example shown in Figure 4, where a gravestone of a deceased person is used as a promotion for a movie. Finally, two participants mentioned how multi-sensory modalities of UAR could be used to more invisibly 'label' a person or location to cause social and psychological harm *"that's even worse, isn't it?? I can have a smell coming from me! I can also tag somebody with that for sure …[to] make somebody feel horrible while you are walking past something …a sort of seed, every time you get near this kind of person, you feel, a certain way."* (George).

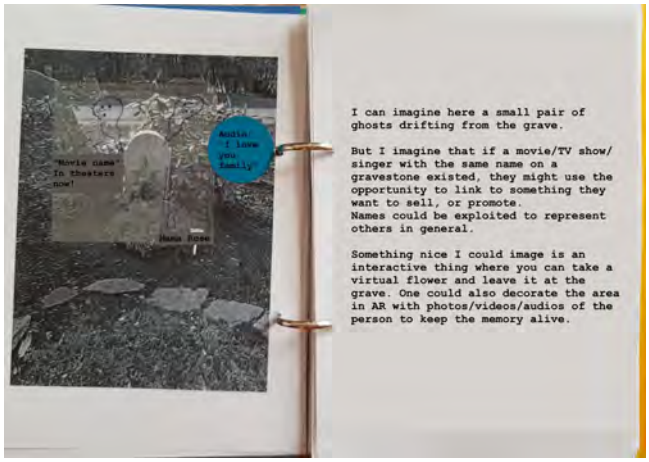

Figure 4: Participants elaborated in textual form on their ideas (here: augmentations on a graveyard). Text reproduced for legibility and anonymity.

4.2 Altering Perception Can be a Harm in Itself

As a part of AR, the physical reality is overlaid with digital augmentations such that a user's view of the world, others, and themselves, can result in altered perceptions. Designers and developers strive to make augmentations as realistic, and multi-modal as possible. While this is what gives AR its draw, it can, and likely will, also be (mis)used to intentionally change the viewer's perception of the world.

Our participants suggested a total of 41 situations where potential **deceptive patterns that alter the user's perception of their surroundings can be used to trick them**, e.g., into taking certain actions. In talking about changing the facade of a building to physically phish a person, Quin remarks how *"'if you have an addiction for games or bars and you are tricked to ending up there'*(Quin). Brent elaborates about an *"AR-placed crosswalk […] placed in the wrong location where traffic is not suitable"* which could cause accidents. We collected examples of intentionally obscuring or diminishing objects or people as perceptual tricks in a surrounding that can cause physical harm, e.g. in Iliana's booklet sketch of a disappeared tree when out for a run. Several of the participants' ideas were based in their unique experiences. Henry, a passionate hunter, exemplifies: *"Some PETA activists just project a nice [augmented] roe deer on the field […] so you can shoot it, and of course you don't hit anything"*. Reflecting on possible consequences, he elaborates during the interview that *"they vanish my car and the projection of the animal walking is in front […] and I shoot my own car"* (Henry).

Following up on potential dark patterns, participants reflected on how malicious uses of **multimodal augmentations might intensify deceptive effects**. Stacy explained *"[…] and there is a sudden sound or smell [in a crowded theater …] maybe it is only for fun or for real […] maybe people are going to protect themselves and do some actions."* Participants pointed out how multimodality

may be purposefully used to exploit triggers, e.g., by finding *"[…] those things that people are super afraid of and show it to them for a moment"* (Alex) through combined audio and visuals, or intensify redirecting users attention, e.g., by *"vibrate[ing] or have[ing] a sound or something like that […] steers your attention even more at things you would normally not look at"* (Jack).

Yet, even when designed with best intentions in mind, **believable changes to the physical environment can alter perceptions of places, persons, or society**. Eight of our participants reflected on one or multiple types of 'beautification', e.g., by blocking out, or altering undesired aspects of reality. Illana noted *"if you block or someone blocks me, they would never show in my glasses. But I think it would actually be helpful."* Even though seemingly benign, familiarization with 'beautified' views, may be a harm in itself, as explained by Quin: *"It is more like a drug addiction thing because you cannot perceive the world the way it is any more without the extra spice of color and animation [provided through the AR system]."* Notably, what is perceived 'beautiful' may be subjective, and 'beautification' a transgression of personal rights: *"the glasses shows them some kind of approximation of someone nude"* (Jack).

Taking this line of thought a step further, UAR can **exacerbate the divergence of multiple perceptions of the same (physical) reality** through altering perceptions of places, persons, and society. George discusses a scenario where poverty is removed from view and reflect on its broader societal impacts: *"It is kinda the attitude of the affluent, to pretend as the other half [impoverished community] doesn't exit […] but the intention I don't think is to grow plants, but it is to block."* For illustration he points to his booklet which shows the path to his home with an augmentation blocking out a path to a less well off part of town (taken up by Scenario 4). Penny discusses in the interview that *"[…] you could have noises of gunshots [that] make you feel very unsafe in that area. Or on the opposite side, you can have a politically motivated thing that could try to erase that by putting something else in that place [...] kind of smooth it over in a way and pretend it never happened. You […] paint it in different lights to convey a very different message and put people in a very different psychological state about a place"* (Penny). The misuse of perceptual tricks feasible in UAR for political means and to create rifts in communities were also voiced concerns discussed in Emily and Nichole's interviews.

4.3 In AR, Sensing is Inherently Ubiquitous

Without accurate knowledge about the physical surroundings, only non-reactive 2D-overlays can be created. So, to enable AR's key characteristics, i.e., to merge real and virtual to be correctly registered in 3D, tracking (some part of) the real-world environment is inevitable.

Users and non users everyday existence in a UAR future can cause a **trail of breadcrumbs which could lead to new ways of inferring information** about them. Jack found such environmentally captured information more problematic for others than himself as *"It is less about what it would do to me but what would I imagine can happen to other people, especially women."* Nichole shared a similar concern about how seemingly harmless augmentations created by individuals, if left around, could eventually lead to clues inferred by opportunistic stalkers. She drew sketches in her booklet of *"Women Wine Wednesdays here!"* with an arrow pointing to a window and in another image had an augmentation saying *"Anna's house – This Way!"* with an augmented bunny on the sidewalk. George and Penny both have the idea of augmentations also aiding thieves, such as in Penny's sketch of a heatmap augmentation over a building of the residences inferred movements within to *"[…]tell there are certain locations that are not frequented as often,"* thus lowering boundaries to what wouldn't normally be so readily and accurately visualized on location.

Various sources of information may aggregate through proximity. Six participants mentioned concerns about how they, or others, would be approached by strangers while using such a system. Quin elaborates in the interview, *"They have their profile picture of tinder or bumble. Even if you choose to hide your profile, you still have your photo and name. If it is not your photo, or it is one of your cat, I walk by and I see your profile. I can really check you out"* (Quin). Additionally, new information can be inferred and displayed by the system and tagged to you as *"There is always a system analyzing the data in some way and potentially saving it"* (Jack) which can cause unwanted invitations to be approached.

Data that is inferred by a UAR system can reveal sensitive or misinterpretable information. In her booklet, Penny drew a heat map augmentation over a building which inferred the movements of residence within. In her interview she elaborated how this information could be used by a thieves to *"[…] tell there are certain locations that are not frequented as often."* Additionally, inferred information could be more easily mistaken to be accurate or reliable because it is situated in UAR like in Brent's example where someone projected flood data on a river they want to build a playground next to, without the right background *"[…] not [be] aware of the fact that the model trust is not that good […] and it is not applicable to your situation[…]"* despite it's high resolution in AR indicating otherwise. Additionaly, physiological information inferred by a system could be embedded into augmented content as was Iliana's idea. During the interviews she speculated how such information could maliciously be used to attack someone in a vulnerable state *"And maybe when the attacker felt that this singer or people who I don't like, they have a bad situation or emotion, it is a really good chance to do something harmful to them"* (Iliana).

Interacting with AR may give away personal information, both purposefully or unintentionally. In the interview, Jack described a situation where *"the system knows what kind of people you are attracted to because the Google cookie looks at what stars you follow. Once you look through a group of people to a person that fits your criteria, it could play 'let's get it on' or something like that"*. On the visionary topic of going to a physically real cafe with an augmented virtual idol as your date, Stacy exclaimed how interactions with augmentations in a public space could disclose embarrassing or personal information *"I am worrying if this is AI, if this idol, or virtual character, will say things that is inappropriate in a public area"* (Stacy).

5 REFLECTION: DARK SCENARIOS AND ANTIDOTES

We present eight speculative scenarios in response to our research question: *What dark patterns and anti-patterns may arise from a*

ubiquitously Augmented Reality? Speculative scenarios are a method to articulate conceivable challenges in a potential future [73]. Similar to design fictions, they aim to open up a space for discussion by sketching out what can (but not necessarily will) happen [54]. Yet, they have a stronger emphasis on believability. Our scenarios are a synthesized version of ideas based on the participants' lived and imagined experiences as described in the previous chapter. Taking inspiration from prior work [32, 88], we base our scenario around a fictional, commercial UAR platform: Always Augmented. The scenarios we present range from close-to-realistic to visionary and exaggerated. Exaggerated ideas may seem far-fetched at times, but they are powerful tools to uncover overlooked or less accentuated risks and harms [81]. Undoubtedly, if there is a way to misuse a novel technology, someone will find a way to do so.

For each scenario, we present: a narrative (*in italics*), a description of how the scenario is specific to UAR and has the potential to materialize based on existing work, then conclude with antidotes. By articulating concrete scenarios it becomes possible to name and describe plausible, deceptive tactics and patterns that UAR could entail. In turn, this allows an outlook for opportunities through technological solutions, i.e., antidotes. The scenarios are presented in an order of which the antidotes can build on each other to create an eventual system concept.

Scenario 1: Unintentionally Along with It

You are resting on a park bench when you catch sight of your old friend from college wearing the new Always Augmented system, a novel platform delivering ubiquitous Augmented Reality to people's smart glasses. They quickly exchange a glance and quicken their pace to walk away. You are surprised by this as you were excited to catch up with them. Unfortunately, neither of you knew that the "Need Money Now" augmented sign floating above your head on the bench was referring to the park in need of fountain reparations.

The spatial, location-bound nature of UAR intensifies existing challenges: augmentations are situated in physical space but not necessarily seen (or perceived) by everyone in this space. This makes them hard to predict for bystanders. Along similar lines, Rixen et al. [75] argues that perceiving information augmented to passers-by reassembles 'socially browsing'(cf., Wise et al. [86]). Rixen's work showed that impact of non-consensual, non-self-disclosed information is perceived as more severe when displayed in AR, as compared to on a smartphone's news feed [75]. They report passers-by (who are not direct users) to perceive increased feelings of discomfort which are intensified due to co-location. Future UAR systems may give rise to non-consensual, and potentially harmful information display on, or around unsuspecting bystanders. We anticipate that limited access to (costly) devices required to display UAR (e.g., smart glasses) may further exacerbate this asymmetry. Vulnerable groups with limited access to specific devices such as children, persons with low income, or without access to specific (e.g., visual) modalities will likely be put at risk.

Bullying in the context of, and/or by the means of technology often includes capturing and sharing information without consent (e.g., so-called internet memes) which may cause severe psychological, social, and financial consequences [42, 44]. The location- or object-bound nature of AR causes co-location, proximity or even distinct visual features (e.g., textures) to suffice to attach a virtual 'label'. Here, basic technological principles behind AR (e.g., the use of visual features as tracking targets) could promote misuse: the relative ease and plausible deniability of 'label attachment' based on environment features. Combined with the ubiquity of a platform such as Always Augmented, this may create perceived anonymity, which has (in other contexts) been observed to reduce the sense of accountability for harmful behavior [91].

Opportunities for Antidotes. A potential technological remedy to non-consensual or unintended, accidental AR annotations is to provide users with agency over annotations in their immediate proximity, i.e., their personal space. This could be realized by taking up Benford and Fahlen's concept of *auras* which are attached to people in an environment [8]. Auras can contain accessible and curatable information – information that is necessary to interact with other systems and devices, as well as information that shall be seen by other people. Benford and Fahlen sketch out how auras serve to control the range of information received from other systems and the environment (so-called *focus*), as well as the range of information broadcasted (so-called *nimbus*). This principle allows to define the extent a user is perceivable by the environment and others. It is also transferable to UAR. Applying the principles of *aura*, *focus*, and *nimbus* to UAR would enable users (and secondary users) to be surrounded by auras which repel non-consensual virtual augmentations as they move through the environment, while maintaining the ability to self-disclose information and interact with augmented information present in their proximity.

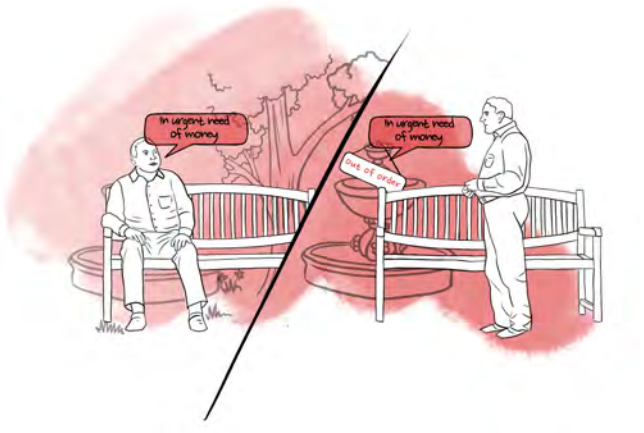

Figure 5: AR annotations are virtual but located in physical space which makes them hard to predict for bystanders. Scenario 1 illustrates how a bystander can be unintentionally 'labelled' by an augmentation.

Scenario 2: Making Personal Information Public

While waiting at a bus station, you catch a barista on her way to work wearing the Always Augmented staring at you. She calls you by your Steam handle and asks how you like the book Freedom by Daniel Suarez. Baffled, you say you liked it, but she continues to recommend another that 'helped her brother get through his PTSD.' Now thoroughly confused, you ask and she explains that 'People around you have read' on her Always Augmented could only been referring to you – no one else is around. When further prompted, she explains it's easy to infer PTSD when playing games through Always Augmented. Remembering you tried out Always Augmented at the store to play Halo, you are conflicted with this new self discovery.

Anyone can seamlessly pull up a person's profile, e.g., based on social media or a web search, by simply looking at them. Objects and locations also have a history of information, that previously linked or newly inferred information of a person nearby, may be displayed. The information displayed could lead to professionally and socially undesirable outcomes, e.g. like opportunistic voyeurism, stalking, or even worse.

Maintaining privacy on social networks that include both private and public user profiles has shown to be a challenge, because so much personal information can still be inferred [90]. In a future with UAR's 3D tracking abilities, even more sensitive personal information can be inferred rather accurately, like from gestural interactions with such system (currently accurate enough for user authentication [68]), to physiological data [59] that are interpreted through specialized computer vision or sensor fusion models. A user can unknowingly grant serendipitous access to personal data like health conditions, weight, or sexual preference [61, 74] more publically than they realize, or even discover this private information about themselves during interactions with UAR. The risks and challenges are intensified in UAR as record linkage of personal information becomes more localized, depicted in the Marius Sixtus' Mockumentary 'Operation Naked'[4]. Deceptive design patterns discussed by Greenberg et al. [38] in the context of proxemics can already give a glimpse of possible (commercial) exploits, e.g., weight shaming to motivate people to sign up for a fitness club. Additionally, persons that are 'local' such as family, co-workers, or neighbors can combine their background information from heterogeneous sources with what is presented digitally, which allows them to make inferences that exceed the information provided by a single data source [71]. Even if not directly tied to an individual, augmentations tied to specific locations may provide 'access' to vulnerable groups, e.g., facilitate harassment or (cyber-)stalking.

Opportunities for Antidotes. UAR poses threats to user and bystander privacy. Extending Benford and Fahlen's *auras* [8] to include access rules (and rights) may open up a space of potential antidotes. Following this line of thought, an aura's owner (i.e., a human) could be quantified and understood by a digital system, such as Always Augmented, as a set of human properties with default access rights. This allows to encode protection of personal rights during system design. For instance, available system's capabilities (e.g. in terms of access to biosensors or environmental sensors, etc.) may be tied to what is required by the current task. In a future UAR system, the same sensor may yield high quality pose information or gaze data to support two-player games, but provide only down-filtered information on casual bystanders. Here, solutions could potentially be derived from established principled for IT systems access rights, controlling who is allowed to read, write or modify information [31, 67] even after it has been duplicated and shared across distributed system infrastructures [69]. Information brokers may be established to negotiate access to other UAR systems and users on behalf of a user's customized personal information and privacy criteria. Responsible for requesting and lending data as well as managing the borrowed information's expiry, information brokers may be one of possibly several pathways towards ensuring personal rights within a ubiquitously augmented reality.

Figure 6: Annotations in AR (here: a pin dropped at a Sakura viewing location as in Scenario 3) are 'only' virtual, but can have real-world impact causing physical harm and alterations to the environment, e.g., by attracting crowds.

Scenario 3: Virtual Effect, Real-World Impact

You have been looking forward to cherry blossom viewing and as you are heading to your favorite picnic spot, you are confronted by disastrous scenery: the area has been trampled, litter scattered, low hanging branches of twigs broken off and scavenged! After your initial shock, it dawns on you: your pal Jenny posted your spot as the 'most beautiful viewing location' on Always Augmented and marked the hidden pathway leading up to it with an augmented arrow. You silently curse her arrow having incentivized too many passers-by to 'just take a look.'

Even though the effect depicted by Scenario 3 is already well-known, UAR can intensify its consequences. Locations that are made prominent through media and are often observed to be overrun by visitors, e.g., lavender fields popularized by Instagram [39].

[4]Operation Naked, 2016, https://www.imdb.com/title/tt5570840/, accessed 15-09-2022

The unintentional temporary invasions of crowds may occur at locations that are unprepared and lack the infrastructure for a large volume of visitors. Pòkemon Go (a popular location-based AR game) has been noted to cause previously deserted public places to attract large crowds [56]. However, ubiquitous AR has the potential to exacerbate this effect by changing its granularity: people that are already in the area are drawn in 'just to take a look,' and they are attracted to more precisely indicated locations. Our scenario was inspired by our study participant Quin, who contributed an example based on her lived experiences in Japan: *"Have you been to Japan? Then you definitely understand the problem of finding the perfect [Sakura viewing] location."* Although many people may travel to Japan to see Sakura (famous cherry blossom), only few might find their way to a specific spot. This demonstrates the necessity of anticipating how AR, not only displaying the physical but being co-located with it, could have real-world negative impacts. For instance, by causing an accumulation of visitors – even at small, otherwise hard to locate spots. After all, what is a 'large' crowd is location-dependent: one hundred additional visitors might be inconsequential for a tourist site but a significant disturbance in a backyard.

Opportunities for Antidotes. Mitigating real-world negative impacts of UAR could harness a system wide level of context awareness. Algorithms like google maps already use such information to re-route traffic, although this could be an exploit in itself [17]. In UAR, the context of determining if a location is crowded can be gathered based on users auras and individual information brokers. Borrowing from a concept of foveated rendering, presentation of augmentations could be based on available contextual knowledge to help determine the level of granularity shown. For example, if a location is very crowded or has many visitors, the arrow from the augmentation or mentions of a exact location could be omitted if you are nearby until the area clears up again. The augmentation about a 'beautiful spot' would still be shown which eliminates the moral quandary of re-directing people or keeping information from them, by showing the situated augmentation at different 'levels' based on context.

Scenario 4: Rose Tinted Glasses

You walk by a restaurant and notice beautiful decorations as a part of the facade. You take off your Always Augmented glasses to clean off a smudge and notice that the rose bushes in front of the building were just photo-realistic augmentations. You also see a homeless man crouching next to the entrance to keep himself warm. Seemingly, he was deemed 'unpleasant' by the restaurant manager and had been diminished from your view.

Augmented reality virtually modifies reality in real-time. This can have a 'filtering' effect. Video filters are already implemented in several contemporary social media and communication platforms, where they realistically blend the virtual and the real, for instance by 'beautifying' the user's face during a video call [45]. Observations reported in prior work indicate that virtual 'beautification' and the resulting altered perception (e.g., of one's self) can have long-term psychological consequences, including so-called 'selfie dysmorphia', where visually enhanced selfies lead to lowered self-esteem [72]. This risk of perceived body distortion is intensivied in UAR, as the modification persists in real-time and, thus, is more realistic [45]. In our ideation study, participants further envisioned a range of these alterations of perception, encompassing both AR, as well as its extension, Diminished Reality. Diminished Reality shares AR's basic principles but, instead of augmenting additional virtual information on top of the physical reality, it seemingly removes physical elements from sight (comparable to impainting) [47]. Extrapolating these ideas illustrates how UAR 'filters' may expand the scope of negative effects from personal towards severe and unwanted societal risks, such as the removal of poverty from sight (cf., Figure 7).

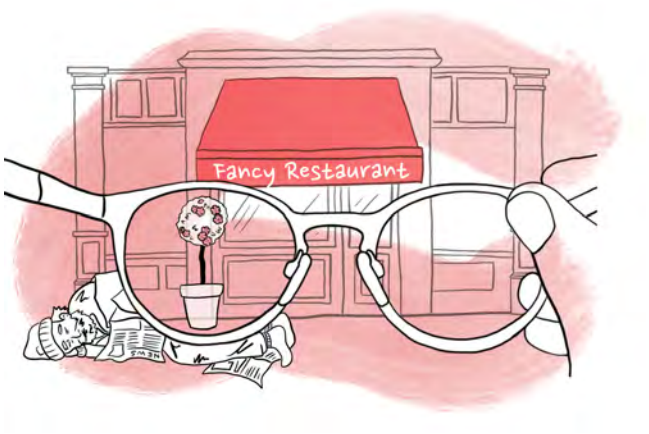

Figure 7: Comparable to filters, UAR has the potential to 'beautify' the physical environment, as suggested by Scenario 4. Even though benign on a first glance, this may bear severe and unwanted societal risks, such as the removal of poverty from sight (depicted).

Opportunities for Antidotes. The concept of ephemerality in novel user interfaces and social media can be used to inspire solutions about the divergence between a user's augmented and physical reality that can grow over time. Ephemeral user interfaces have an 'expiration,' depending on the material and reason for their fleeting interaction window [27]. This concept exists for social media posts with positive effects, such as encouraging sharing and spontaneity without the concerns about self presentation [80]. Similarly, extending this concept to filters in UAR, a filter's ephemerality can enhance its beauty as events in nature (like sunsets). Ephemerality of filters can also be an intentional design consideration to combat the current limitations of AR (power consumption of heavy computational filters running on a wearable device, lapse in tracking, and lack of clarity of holograms due to dynamic lighting conditions in the environment, etc.). Not all filters should be ephemeral, e.g. ones used for surgery or industrial applications. However, filters in professional contexts may have additional regulations that increase a user's awareness about aggregate perceptual divergences that more pervasive filters in the vein of 'beautification' may not. Ultimately, technological means can not (necessarily) remedy societal issues,

such as defining 'beauty' and what might be considered an ethical 'beautification' filter.

Scenario 5: Mismatched Worlds

Your partner and you are both in the kitchen preparing dinner on instructions through you respective Always Augmented systems. You've enabled a filter to diminish the kitchen clutter and noise of your partner washing dishes and they have enabled a filter that gives the illusion of items looking lighter to make chores seem more convenient. You asked your partner to pass you the knife. Between your mismatched your diminish filter and the mismatched force of your partner handing the knife to you, you cut your hand upon receiving the knife.

Augmented Reality possesses the potential to be inherently asymmetrical: different users can share the same physical environment, but view different virtual representations overlaid as augmentations. This divergence may, for instance, result from differently defined AR application preferences, discrepancy of system settings, or asymmetric hardware abilities. This results in 'mismatched worlds' which can create challenges that may – eventually – result in harms. For instance, conflicts can occur when multiple UAR users are located in the same physical environment but interact with diverging augmented overlays. The resulting conflicts share similarities with collisions between VR and a user's physical surroundings (e.g., the risk of hitting walls [22]), but also introduce new challenges: especially co-located interactions involving diminished or virtually transformed physical objects (such as the knife in Scenario 5) may believably alter the user's perception of reality, while their actions are still rooted in the physical world. This may also put bystanders at risk as they have difficulty anticipating the actions of the user[22]. Malicious attempts of deception may take up principles known from VR to exploit perceptual illusions, e.g., so-called Virtual-Physical Perceptual Manipulations [82]. Creating perceptual illusions in AR, including altering the perceived softness of object [70], the weight-size illusion [76], changing the perceived flavor of food [63], or the rubber hand illusion adapted for supernumerary limbs in AR [77], display not only the potential of AR as a technology, but also its potential for malicious deception. In this context, 'mismatched worlds' opens up a space of deceptive patterns where the user's trust in their accurate perception of, and reaction to, the physical world is exploited.

Opportunities for Antidotes. There already exist designs for transitioning between virtual and physical realities to create seamless interactions [35] while minimizing the cost of immersion loss [53]. Instead of transitions between physical and virtual realities, similar metaphors of windows, doors, portals into the other's augmented realities can also be used for awareness of co-located collaborators across varying UAR views. Making it explicit if the augmented reality is a shared space when interaction is necessary. Finding the rules and adjustments to blend two user's different augmented realities to meet 'in the middle', without disrupting the immersion of both UAR users, could solve jarring conflicts. Dangerous objects or locations, based on an evolving registry, can have limits to how they are filtered or have the 'photo-realistic' granularity of the filter reduced. What information is shown or revealed when two augmented spaces merge can be in part negotiated by the information broker (from antidote of Scenario 2). We argue that this solution will not solve malicious attempts to cause harm, but rather mitigate unintentional consequences, and that until research on effects of filters continue to develop, other interventions may be needed (infrastructural/environmental, regulatory, or limits built into the hardware).

Scenario 6: Attention Grabber

You get an augmented notification about a discount at a local pizza shop a few blocks away. You then hear a customized message, calling you by your name in your mothers voice, then the ad hits you with an artificially engineered pizza smell. If you still haven't looked, your Always Augmented system vibrates until you turn your head in the direction of the shop while you try to navigate a heavily trafficked pedestrian walkway.

In a perfect, ubiquitously augmented world, people would be in control of the technologies that enable them [84], such as in UAR, which could potentially appeal to any of the human senses. However, this also means that in UAR, attention seeking augmentations could possibly befall the user at any time, anywhere causing sensory overload and a less calm ubiquitous experience [6]. Similar to existing deceptive design patterns centering around pop-up windows in 2D web-browsing, the user is distracted and kept from reaching their initial goals. In contrast to their 2D counterparts, these augmented distractions cause the user to become less situationally aware and can induce physical dangers, a danger that has already been observed with smartphones [79] and has growing concerns to occur in AR [78]. Augmented distractions could be used as a tactic for manipulative marketing as explored by Mhaidli et. al. [60] and exacerbated in UAR through pervasively situated multi-sensory augmentations (auditory, haptic, olfactory). Deceitful attention grabbers can strongly elicit emotions overtly, or even subconsciously, through various senses, e.g. how certain scents have been shown to encourage behavior change [23].

Opportunities for Antidotes. Previous work has thought about intelligent placement of holograms to minimize distraction in AR [1]. However, the growing number of ways our attention could be hijacked is ever evolving. Certain safe hardware limits could be implemented (e.g. maximum volume, certain pain or injury inducing haptics, or scents that are regulated and not allowed) although widespread limitations like this could reduce utility in certain special contexts. The system can have an evolving ad blocker or spam filter to match the level of evolving exploits, although some such solutions come at the cost of privacy. Such a dark scenario may not be fully combatted by technology-based interventions and require additional interventions like regulatory measures.

Figure 8: UAR can unite ideas and opportunities in one location, as illustrated in Scenario 7. This can short-wire reason and lead to rash, and possibly dangerous, activities, such as taking a bobby car on a slide.

Scenario 7: Challenged Impulse Control

You have recently gotten your Always Augmented system and right now, you and your classmates are celebrating the end of the semester. On your walk to the university dorms, you come past an overly condemning virtual sign on a playground: 'It is forbidden to slide with a bobby car'. It does not seem to be official, and normally, it wouldn't interest you, but the mood is jolly and you and your companions are a bit tipsy from celebrating. Your attempt at performing the self declared challenge down the slide with a bobby car (in order to post on Always Augmented) ends in the emergency room.

Incentives to attempt dangerous activities may be fueled by immediateness of a call-to-action prompt and social peer pressure. Recently, challenges, including dares to replicate dangerous stunts or experiments, have spread on social media (e.g., TikTok) and resulted in a growing-number of severe and fatal injuries [4]. Again, the situated nature of UAR, possibly fueled by novelty and excitement, could pose the risk of users creating more persuasive challenges. Moreover, there is the risk of dangerous business practices [36] and deceptive design patterns that are purposefully crafted to intentionally short-wire reason. On-the-site augmentations may be designed to intentionally trigger a bad habit or addiction (e.g., for profit). This scenario goes further to illustrate how phenomena, such as the Werther effect or copycat suicides [64], could be fueled through co-location of an opportunity and a trigger resulting in severe consequences: our participants had pointed out how suicidal ideation incentivised by UAR occurring at locations, could afford a suicide attempt. The resulting immediateness can hinder re-evaluation that would lead to a change of mind or external live-saving intervention (e.g., by family or therapist).

Opportunities for Antidotes. On social media, content moderation is costly, hard to automate, and takes a toll on the content moderators [21]. Even though it is possible to train machine learning models able to recognize patterns of harmful content (such as violence in videos [24] or hate speech [18]), unintentional incentives (as illustrated in Scenario 7), or purposefully deceptive elements making use of loop-holes (as described by Ayeni et al. [5]) may be hard to classify correctly. Thus, albeit an active and essential research area, the extent to which technological interventions may be effectual is limited. Here, Scenario 5 to Scenario 7, a combination of social, legal and regulatory interventions as well as platforms (like the fictional Always Augmented) taking on responsibility will be crucial.

6 DISCUSSION

We reflect on this work, its potential implications, limitations, as well as the extent to which technical antidotes could deliver on their promise.

Effectiveness of Antidotes. In this work, we discussed antidotes (i.e., technological remedies) and relate them to each of the presented dark scenarios. Yet, technical solutions designed to mitigate deceptive design patterns in UAR also possess inherent limitations. Firstly, it might not be possible to anticipate all facets of UAR's prospective deceptive design patterns. Next, the antidotes suggested aren't the sole solutions to the dark scenarios we presented and implementing technical countermeasures may lead to ever more adapted and sophisticated exploits. For example, the antidote of Scenario 5 suggests transitioning or merging two different users augmented realities. Depending on how the 'merging' of realities are handled, it can cause information leaks based on what is showed or could be inferred in the now shared augmented world. Additionally, (un)-intentionally being merged with someone with extreme 'world settings', could be jarring (e.g. your diminishing audio filter's sound spikes up after merging with someone's augmented world using their AR system as a hearing aid) and even be preformed maliciously. Along with antidotes to Scenarios 5-7, we discuss our anticipation for regulatory or social countermeasures. However, even if available, technological antidotes would need to be carefully evaluated against regulatory or social countermeasures – balancing expected costs against benefits is crucial.

Technology cannot fix all of society's problems, but it can inherit them. The discussion motivated from our analysis highlights how multi-disciplinary perspectives, including technological views, but also political and social sciences will be required to be able to fully mitigate what may become of our envisioned dark scenarios. As alluded to in several of our scenarios, UAR is inherently asymmetric: unequal access to costly hardware, or the lack of accommodating of peoples various roles and abilities as UAR continues to develop, can cause societal imbalances. In parallel, differences in the granularity of what is visible or functionally accessible in UAR may have a real-world impact, e.g. if widely adopted UAR content is only accessible through paid subscriptions, or not every UAR user has equal access to place or use augmentations that can benefit them. Similarly, UAR is susceptible to existing exploits that we encounter in social media, e.g. misinformation, socially engineered scams, etc., as well as privacy concerns of context-aware and ubiquitous systems, and lastly systems security vulnerabilities which we did not speculate on in this work.

Limitations. In this work we provide a list of speculative scenarios that were co-created over several months with globally dispersed participants. Due to the long spanning nature of our ideation method, some of our participants dropped out and two of our internationally located participants never received their booklet due to Covid-19 shipping delays and had to print them out or digitally annotate them. Flexibility in schedule and consistent communication were key as during the study multiple participants were going through transitional life events (e.g. moving, marriage, new jobs, surgery, pregnancy, etc.). While this allowed to based our analysis on diverse experiences, more than a brainstorming within the research team would have yielded, the list of dark scenarios still is not exhaustive. Some plausible scenarios might have been missed either due to the selection of participants or the authors' own lens of analysis. Other authors (e.g., coming from less tech-positivist perspectives) might have compiled a different set of scenarios taking the participant's ideas as starting points. Nonetheless, we believe that our scenarios may serve as valuable openers for a critical and timely discussion that map out (at least some of) the dark consequences emerging from UAR.

7 CONCLUSION

In this paper, we critically reflect on seven 'dark' scenarios that articulate how, in a near future, Ubiquitous Augmented Reality may be used to create deceptive designs taking advantage of users, or could lead to unintentional, but still equally harmful negative consequences. The scenarios are a result of creative co-speculation with 12 globally located participants and embed their diverse backgrounds and lived experiences. A thematic analysis of their ideas further identified three overarching themes: (1) Situatedness in of Information in UAR Causes New Types of Risks, (2) UAR Altering Perception Can be a Harm in Itself, and (3) In AR, Sensing is Inherently Ubiquitous. We contribute a discussion of the extent to which these envisioned, but probable, harms could be addressed and mitigated. To this end, we critically reflect on concepts for technological antidotes, and the extent to which they might be effective. We believe that it is timely to gather dark UAR scenarios and open up a discussion on its potential misuses; Starting already today, in the early phase of the emergence of UAR. This head start is crucial to avoid building dystopian technologies that abuse instead of empower users.

ACKNOWLEDGMENTS

This research was partially funded by the Responsible Innovation Initiative "Consider Everyone" of Meta Reality Labs. We would like to thank our participants for their generosity in sharing their time and ideas.

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