Ad-Blocked Reality: Evaluating User Perceptions of Content Blocking Concepts Using Extended Reality

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Abstract

Inspired by the concepts of diminishing reality and ad-blocking in browsers, this study investigates the perceived benefits and concerns of blocking physical, real-world content, particularly ads, through Extended Reality (XR). To understand how users perceive this concept, we first conducted a user study ($N = 18$) with an ad-blocking prototype to gather initial insights. The results revealed a mixed willingness to adopt XR blockers, with participants appreciating aspects such as customizability, convenience, and privacy. Expected benefits included enhanced focus and reduced stress, while concerns centered on missing important information and increased feelings of isolation. Hence, we investigated the user acceptance of different ad-blocking visualizations through a follow-up online survey ($N = 120$), comparing six concepts based on related work. The results indicated that the XR ad-blocker visualizations play a significant role in how and for what kinds of advertisements such a concept might be used, paving the path for future feedback-driven prototyping.

CCS Concepts

• **Human-centered computing** → **Mixed / augmented reality**; Ubiquitous and mobile computing systems and tools; *Empirical studies in ubiquitous and mobile computing*.

Keywords

Extended Reality, Content Curation, Visualization, Physical Ad Blocker

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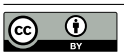

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1 Introduction

Extended Reality (XR) can reshape how we interact with reality. As an umbrella term [54], XR spans concepts for altering the perception of reality from overlaying or embedding virtual elements in physical reality (i.e., Augmented Reality (AR)) [39] to interweaving physical and virtual stimuli (i.e., Mixed Reality (MR)) [61], or even fully immersing users in a virtual environment (i.e., Virtual Reality (VR)) [27]. In addition to adding content, XR may diminish or obscure aspects of virtual or physical environments by filtering out certain elements (i.e., Diminished Reality (DR)) [9]. XR transforms how we interact, perceive, and interpret physical and virtual content through these capabilities. Consequently, XR will empower users also to block ads and other undesired elements [53] in virtual and physical environments, creating more personalized and distraction-free environments. This ability to filter out intrusive content might enhance focus and well-being, allowing for more intentional interactions with digital and physical spaces. The idea of content blocking has become compelling in academic research. Previous work suggested blocking users in XR for privacy-preserving measures [46] or content through diminishing reality, consequently presenting different visualizations for obscuring real-world content [9].

The most prominent instance of existing widespread content blocking is web-based ad-blocking. Here, certain parts of a website are blocked from loading [20, 64] to avoid the presentation of ads. However, such content blocking only affects virtual content in a virtual 2D environment and thus does not directly affect users' perception of reality beyond the screen where the website is presented. In contrast, ads in virtual and physical 3D environments, such as VR or AR games, are much more directly embedded in users' reality, especially when physical ads, such as billboards or posters, are not as easy to block. A physical approach would be to cover ads with different physical content, as done by *adbusting* activist groups. XR devices, however, offer a technological means to detect and block or replace physical ads using virtual methods.

XR content blocking can positively and negatively impact users and society. On the positive side, it allows individuals to filter out unwanted distractions, such as ads, creating a more focused and personalized environment [37]. However, the negative implications are more complex. Excessive content blocking could lead to information silos [50], where users are only exposed to content

that aligns with their preferences or beliefs, reinforcing biases and limiting diverse perspectives [62]. Additionally, it could disrupt the economic models of content creators and advertisers who rely on visibility in these spaces. This selective filtering might also reduce opportunities for spontaneous discovery, limit exposure to new ideas, or hide valuable information in safety-critical environments [16, 23, 24], ultimately narrowing the scope of the user's experiences and understanding of the world.

To understand how users perceive and prefer content blocking in XR, we first conducted an in-person user experience study with 18 participants to investigate how users perceive ad-blocking in XR environments. Utilizing a working prototype for content blocking, participants were able to experience the ad-blocking functionality firsthand and provided feedback on its advantages and disadvantages. While many appreciated the ability to remove intrusive or unwanted ads, several expressed concerns about the potential to block content that may be relevant or important inadvertently. Additionally, some participants worried about the possibility of the ad-blocking feature being manipulated by malicious actors to suppress critical information or promote harmful content, highlighting the need for careful implementation and safeguards in such systems. Based on these findings, we continued our research in a second study to gather more information regarding the potential design of such XR ad-blocking visualizations. We presented six such blocking concepts to 120 participants through an online survey, gathering information about the acceptance and apprehensions regarding such systems. Our results show that hedonic motivation (i.e., engagement and enjoyment) played a prominent role in the overall acceptance of the concepts, and the preferences differed regarding the content that was supposed to be blocked.

Contribution Statement: This research advances the understanding of XR ad-blocking by investigating user perception and acceptance through in-person and online studies, uncovering a user preference for control over advertisements rather than outright removal, with a strong inclination toward visually engaging and manually adjustable blocking methods, while favoring automatic blocking primarily for sensitive content. Additionally, the study highlights a discrepancy between online and hands-on evaluations, showing that immersive testing reveals greater user apprehensions, underscoring the need for real-world assessments to inform the development of context-aware and privacy-conscious XR ad-blocking solutions. Further, we propose that intuitive manual customization, a balance between aesthetics and functionality, and a closer look at non-academic sources for future work should guide future development and deployment of XR ad-blockers.

2 Related Work

The idea of XR ad-blockers combines multiple research areas that drew attention in Human-Computer Interaction (HCI) research: *Diminished Reality*, *advertising in XR*, and *ad-blocking in digital spaces*. We elaborate on previous research in these areas.

2.1 Diminished Reality

XR is often considered as a modality for *adding* virtual content or *augmenting* physical objects in the real world. Yet, it also enables selectively *removing* or *reducing* the visibility of certain real elements in a user's visual environment. This concept is known as *Diminished Reality* (DR), or *reduced reality* [19, 75]. Other terms include *deaugmenting* XR [7] or *visual noise cancellation* [21]. Steve Mann first discussed DR in the 1990s [33, 34], but the concept has only recently received increasing attention [9, 42, 43] following the increasing availability and capabilities of XR devices. This approach enhances the user experience by eliminating unwanted visual clutter or distractions, thus simplifying the visual environment of users [21]. While DR is mostly associated with visual perception, removing stimuli is already prevalent in auditory perception through noise cancellation headphones [19, 40].

Previous research investigated different methods for operationalizing DR. Mori et al. discuss four techniques: *Diminish* to "[degrade] visual functions for a certain purpose", *See-through* to "[cover] real objects with images of their occluded background to make the objects virtually invisible", *Replace* to "[overlap] a real object with a virtual object so that the real object appears to be replaced by the virtual object", and *Inpaint* to "[generate] plausible background images based on the surroundings" [42, p.2]. Cheng et al. investigated seven visual techniques to implement DR in their VR-based study: *reduce opacity*, *reduce opacity + outline*, *blur*, *reduce saliency*, *desaturate*, *reduce contrast*, and *reduce scale* [9]. Brasier et al. describe DR along three dimensions: Trigger, Scope, and Rendering [7].

While this research provides an overview of how DR can be implemented, it addresses the problem from a general perspective without considering specific application scenarios. Certain DR techniques may be useful only in certain contexts or scenarios, while they could be problematic or unhelpful in others. Concepts such as inpaint or replace, for instance, potentially require a lot of computational power that might not be readily available on XR devices, while *reduce scale* might attract more attention for objects where a small scale is unusual. Specific applications using DR have, for instance, focused on helping people focus on their work by reducing the visual clutter in their surroundings [80], providing personalized recommendations in a supermarket scenario by diminishing unhealthy products [66], or creating a virtualized sports game that only shows parts of the game objects and the physical environment [59]. Another situation where DR could be a useful concept is in advertising, particularly when it comes to ad-blocking, a commonly used content-blocking feature when browsing the web [52].

2.2 Advertising in XR

Immersive and interactive advertising using XR technologies has been conceptualized in the past decades [5] and is now increasingly studied [37, 49, 58]. Researchers expect that as XR becomes more integrated into everyday life, advertising will become more immersive and interactive, creating deeper engagement with consumers [2]. For example, companies use XR to create engaging product experiences, such as visualizing furniture or clothes in users' environment[1]. XR devices could give advertisers unprecedented

[1] See, e.g., https://www.ikea.com/au/en/home-design, last accessed on 2025-02-13.

access to personal data, which could then be used to create highly targeted and potentially manipulative advertising campaigns. Thus, robust ethical guidelines and regulatory frameworks are needed to ensure that XR advertising respects users' privacy and autonomy [2, 37, 45]. Additionally to the potential of XR to be used *for* advertising, it could also be used *against* advertising in the form of XR ad-blockers. XR ad-blockers in XR can function like web ad-blockers, filtering out intrusive digital ads from the user's physical environment just as traditional ad-blockers block pop-ups and banners online. This way, people can navigate their augmented world without the distractions of unwanted advertisements.

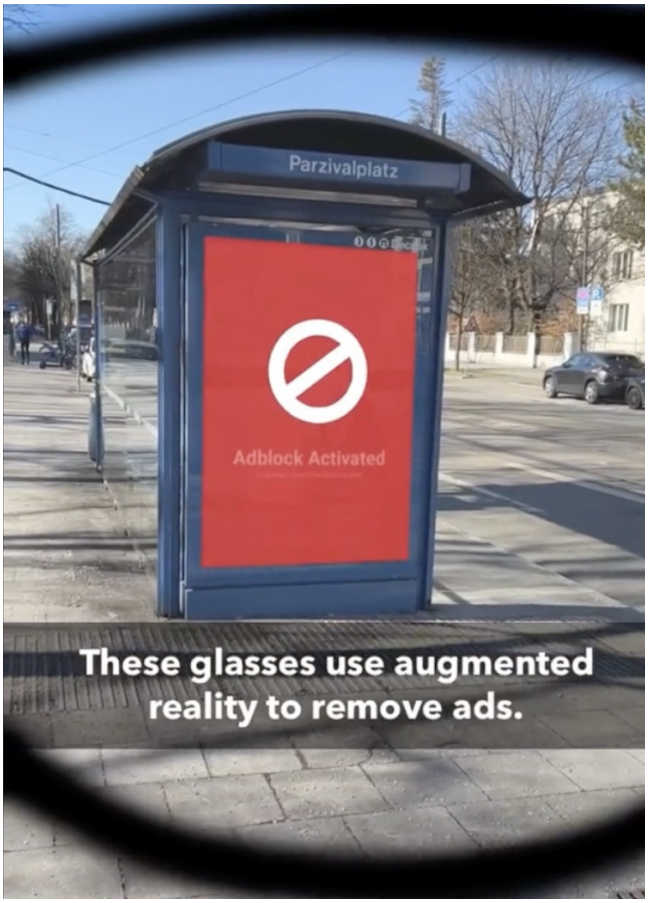


Figure 1: A screenshot of a concept video from a TikTok post by user @designinvr showing how a "real-life adblocker" could look like.[2]

2.3 From Digital to Physical Ad-Blocking

Ad-blocking is employed on the web or on mobile devices by installing third-party software to block specific parts of a website or app containing promotional content [20, 22]. Estimations of how many people use ad-blockers vary widely from 10% to 50%, where culture and gender differences play a large role [20, 32].

Most ad-blocking software relies primarily on filter lists that contain known URLs from advertisement providers that are then blocked from loading [64]. Alternative approaches include perceptual ad-blocking [71], which detects ads based on their visual content. Furthermore, ad-blockers can replace ads with visually appealing content instead of removing ads entirely. For instance, the "CatBlock" browser plugin[3] swaps out advertisements for images of cats, or the "AddArt" plugin replaces ads with artworks[4], indicating that web users may prefer to see enjoyable content in place of ads and appreciate knowing when content has been substituted.

Ad-blocking in VR conceptually constructs a bridge from web-based ad-blocking to the blocking of physical ads. On the one hand, ads in VR are virtual content like ads on the Web and could thus probably be detected and blocked using similar measures. On the other hand, ads in VR may be spatially embedded in the virtual environment, e.g., on virtual billboards in games [77], and thus simply blocking or not showing this content may negatively influence the users' experience and sense of immersion.

Current research on advertisements and VR focuses almost entirely on the marketer's side, e.g., on how VR can be used for marketing purposes [58], or on VR in-game advertising [30], with few studies researching the users' perspective on advertising in VR [36, 37]. Ad-blocking in VR currently receives little attention in research and beyond, limited to users' discussions on ad-blocking in VR-based browsers[5], and user-built tools for blocking ads in social VR such as "AdGoBye"[6]. Research on ad-blocking in XR could thus enable VR users to take more control over which content they perceive in a VR environment.

Although there are several methods for blocking virtual advertisements on the web or on mobile devices, it is far more challenging to block physical ads, such as billboards, magazine advertisements, or posters. A completely physical approach is to simply cover the ad with different content. This practice is used by *adbusting* groups such as Adbusters[7] or DIES IRAE[8] who "[alter] existing brand communication (e.g., a billboard ad) to promote social/political issues (e.g., pro-environmental behavior)[, denounce] the targeted brand (e.g., its labor standards)" [31, p.1], or to promote ad-free environments. Similarly, the "Art in Ad Places" campaign[9] aims to challenge the pervasive presence of advertising in urban environments by using art to create visual and cultural impacts in place of commercial messages. The campaign described public advertisements as "visual pollution [...] being pushed on viewers without their consent." As shown in Figure 2, certain cities, including São Paulo introduced local legislation to reduce the number of inner-city billboards.

Virtual solutions to enable the blocking of physical ads include mobile apps such as "NO-AD" [60] that replace advertising billboards and posters with artwork when the mobile device is pointed at the ad. Similarly, the art project "The Artvertiser" replaced physical billboard ads with art to create an "Improved Reality" using a

[2] https://www.tiktok.com/@designinvr/video/7064633509826317614, last accessed on 2025-02-13.

[3] https://github.com/CatBlock/catblock, last accessed 2025-02-13.
[4] See e.g., https://add-art.org, last accessed 2025-02-13.
[5] See e.g., https://www.reddit.com/r/OculusQuest/comments/1bzx9qj/ad_block_for_browsers_on_oculus/, last accessed 2025-02-13.
[6] https://github.com/AdGoBye/AdGoBye, last accessed 2025-02-13.
[7] https://www.adbusters.org/spoof-ads, last accessed on 2025-02-13.
[8] https://www.instagram.com/nervtjeden, last accessed on 2025-02-13.
[9] https://www.artinadplaces.com, last accessed on 2025-02-13.

custom set of binoculars [47]. Additionally, "Brand Killer," a homegrown solution developed during a hackathon in 2015 by Dubin et al. [14], provides a conceptual non-functional system that blocks brand names and logos using XR glasses. Next to these examples, video montages and discussions on social networks show an increasing interest in such "real-life ad-blockers" (cf. [13, 70] and Figure 1). Such approaches show that it is, in principle, feasible to block physical ads. However, these examples mostly remain in the stage of early prototypes, temporary art projects, or work only in very specific contexts.

Additionally, one major challenge of these virtual approaches is that the to-be-blocked ad's physical position needs to be determined, e.g., using a pre-known location[10], or by using computer vision to detect advertisements when a user is standing before them. Despite these promising developments for real-world ad-blockers, their functional utility and impact on users have rarely been investigated using XR technologies.

2.4 Mitigating Harmful Effects of Advertising Using XR Ad-Blocking

Previous work showed that the development and acceptance of XR ad-blockers may be useful, potentially allowing people to gain more agency over what content is perceived in public spaces. The placement of advertisements in public spaces raises ethical questions about visual pollution [11] and the invasion of personal space [41]. Billboards and posters, for instance, are unavoidable and can impose commercial messages on individuals without their consent. Critics argue that such omnipresent advertising creates a consumerist culture, where the constant exposure to commercial messages encourages materialism and undermines public well-being [41].

Outdoor advertising has also been shown to contribute to health issues [51], violent behavior [3], or sexual harassment [57]. Additionally, researchers have found that disadvantaged and vulnerable communities are disproportionately impacted by harmful outdoor advertising [29]. Because of these potentially harmful implications of advertising, many jurisdictions around the world pose strict regulations for certain types of advertising. For instance, tobacco advertising is tightly regulated in the European Union [15], China [67], and other regions [18].

Given these findings, an XR ad-blocker could serve as a tool to help individuals reduce the potential negative effects of physical advertising. However, it is important to thoroughly study XR content blockers to assess the benefits and disadvantages of a functional prototype in a user experience study. Additionally, a detailed assessment of various DR techniques in different scenarios is necessary to determine user preferences and identify the most effective content-blocking method in each situation.

2.5 Summary and Research Questions

The review of related work highlights several key aspects of the challenges posed by manipulating perception in XR. Using said technology to block advertisements in the real world might be one way of gathering relevant information about its feasibility, public acceptance, and apprehensions about such a use case.

Technological advancements offer the potential for real-time ad detection and blocking within XR environments, but current hardware limitations and privacy concerns pose significant challenges. Ethical and social implications naturally require careful consideration, too. Existing implementations, such as experimental prototypes and conceptual applications, demonstrate the feasibility and potential of XR ad-blocking technologies, but they remain at an early stage.

(a) A street littered with advertisement billboards in São Paolo before a public advertising ban was enacted.

(b) The same street in São Paolo after the Clean City Law was enacted and public advertisements having been removed.

Figure 2: One potential approach to removing disruptive advertisements blemishing the cityscape in the physical real world is outright banning public advertisements. In 2007, São Paulo went such a route with the Clean City Law, as reported by Kurt Kohlstedt for "99% Invisible" (images by Marcelo Palinkas)[11].

[10] Advertising companies such as BillboardsIn (https://www.billboardsin.com) or Outfront (https://www.outfront.com/media-finder) may offer a list or locations. Alternatively, OpenStreetMap (https://openstreetmap.org) may be searched by using the tag "advertising=billboard". All websites last accessed on 2025-02-13.

[11] https://99percentinvisible.org/article/clean-city-law-secrets-sao-paulo-uncovered-outdoor-advertising-ban/, last accessed on 2025-02-13.

Table 1: A summary of the studies conducted to investigate XR ad-blocking technologies.

Study	Aims to answer	Type	n	Independent Variable	Short Description
User Perception Study	**RQ1**	In Person	18	One working prototype	Participants were able to test an XR ad-blocking prototype in a controlled environment and give qualitative feedback.
User Acceptance Study	**RQ2** **RQ3**	Online Survey	120	Six design concepts	Participants were able to give feedback on six design concepts for potential XR ad-blocking visualizations and systems.

The growing popularity of XR devices, combined with the desire to control visual input through Diminished Reality approaches and reduce informational overload through ad-blocking software, leads us to the following research questions, aiming to explore user acceptance and the perceived impact of XR ad-blocking devices on personal, work, and societal everyday life:

RQ1: How much are users inclined to use XR ad-blockers in real-world advertising contexts?
RQ2: How do users perceive different concepts for XR ad-blocking visualizations?
RQ3: How would users operationalize different concepts regarding different types of advertisement content?

3 Methodology

This study employed a mixed-methods approach to evaluate user acceptance and perceptions of XR ad-blocking technology. Table 1 gives a quick overview of the procedure. To address **RQ1**, we conducted an in-person user experience study with 18 participants. In a controlled environment, participants interacted with a working prototype of an XR ad-blocking system, providing qualitative feedback on their experiences, which helped assess their inclination toward adopting the technology.

To answer **RQ2** and **RQ3**, we administered an online survey with 120 respondents. Participants reviewed and provided feedback on six design concepts for potential XR ad-blocking visualizations and systems. This survey gathered both quantitative and qualitative insights into how various design approaches might impact user acceptance and concerns, helping identify which concepts resonate most with users. Both studies received ethical approval from the institutional review board.

Our approach involved recruiting participants from Europe for the first study, as it required in-person engagement, and from the U.S. and Canada for the second study via a crowdsourcing platform to ensure access to diverse participant pools. We aimed to minimize sampling bias within these regions by sampling populations representative of these regions. Although previous work showed potential differences in the perception of concerns between different cultures and regions [72, 76], our sampling pool allowed us to prioritize a representative split of participants in different, albeit similar, Western countries.

4 User Perception Study: Gathering In-Person User Experiences With a Working Prototype

The first study aimed to gather qualitative feedback from participants who used a working prototype of an XR ad-blocking technology. During this study, participants were able to gather user experience in a controlled environment. A total of six advertisement posters were hung up to represent realistic, real-world advertisements that could be blocked by the prototype.

4.1 Apparatus and Setup of the User Perception Study

The prototype builds on the Meta Quest 3[12] and its features to display the blocking elements. As Meta devices prevent third-party apps from directly accessing the video feed, we settled on the OS-implemented feature of "Space Setup". Users can use this feature to tell the Meta Quest 3 application where walls, tables, couches, plants, and wall art are or use the automatic detection feature. This room setup data is saved on the device and can be used by apps to implement XR features using the scene model, which "provides a geometric and semantic representation of the user's space so you can build mixed reality experiences"[13].

Our study used advertisement posters as objects that could be diminished. For this prototype, we decided to mark all placed advertisement posters as wall art, set their spatial anchors, and place a solid dark grey plane directly on top of them. This visually blocks the predefined space and the poster underneath it. The blocking plane is placed directly onto the walls defined via room setup and gets a certain depth to ensure the blocking plane merges into the wall, and there is no part of the poster peeking through a gap between the blocking plane and the wall. The general setup and an example of the blocking taking place is shown in Figure 4.

Users could enable and disable this feature by pressing a controller button, rending all placed blocking planes visible or invisible respectively. No further interactions had been implemented to keep the participants focused on their perception of the surrounding environment. Therefore, no further XR features offered by the Meta SDK, like hand outlines or gestures, were used to blend the experience into the real world as seamlessly as possible.

The study was conducted in a hallway at our local research institute that was inaccessible to the public. Therefore, we mitigated

[12]https://www.meta.com/quest/quest-3/, last accessed on 2025-02-13.
[13]https://developer.oculus.com/documentation/unity/unity-scene-overview, last accessed on 2025-02-13.

(a) An informational advertisement poster for a local festival. (Source: Lollapalooza Festival[14])

(b) An advertisement for a delivery service. (Source: Wolt Delivery Service[15])

(c) An advertisement for a local beer brewery. (Source: Berliner Pilsner Brewery[16])

Figure 3: Three exemplary advertisement posters used in the in-person User Perception Study.

unforeseen interruptions during the study. All trials occurred during daylight hours when the rooms were naturally well-lit. Existing furniture and other wall decorations, like whiteboards and research posters, were kept unchanged.

4.2 Advertisement Posters Used in the User Perception Study

The advertising posters used in the study were actual outdoor advertisements used in Central Europe. These posters were either sourced digitally from the internet or photographed in public and then digitally processed. All images were upscaled to meet the quality requirements for large-scale printing. The posters were selected to represent a variety of real-world outdoor advertising themes, allowing participants to assess the prototype app using a diverse range of examples. They ranged from advertisements for a local beer brand to two gym advertisements with both male and female models, an informational campaign on safer sex by the national government, a festival lineup and date poster, and a food delivery service.

4.3 Procedure of the User Perception Study

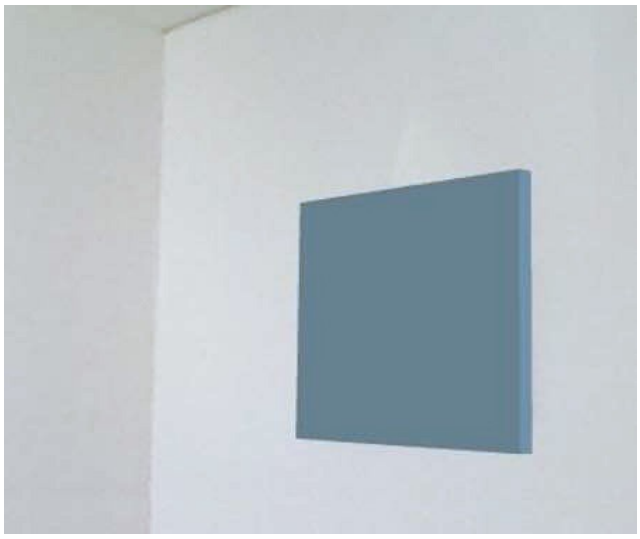
Upon the participants' arrival, they were welcomed and led to the office floor, where advertising posters were already displayed on the walls. Following a brief introduction, participants reviewed the informed consent and introductory sections of the questionnaire on a provided laptop. Participation in the study was voluntary, with the option to withdraw anytime. The participants first completed the initial portion of the questionnaire, which included questions about personal details, prior experience with XR devices, and initial opinions on advertising.

After completing these general questions, participants were asked to put on the Meta Quest 3 head-mounted display. The XR ad-blocker prototype application was already running with the blocking feature enabled, with the study administrator previously ensuring the room setup was still correct. Once the XR glasses were on, a controller was placed in the participant's right hand, allowing them to test the prototype in the room. Participants were encouraged to interact with the prototype freely, using it as they preferred. They had the ability to toggle the feature on and off at will and could move around the controlled environment as they liked. No specific tasks were assigned; instead, they were just instructed to explore the ad-blocking feature in a manner of their choosing to evaluate its functionality. They were given no explicit time limit during this, but no participant took longer than the internally allotted 10 minutes. They were informed that they would be asked further questions about their experiences and the potential use of the concept after testing the prototype. After the participants finished testing the XR ad-blocking prototype, they returned the Quest 3 to the experimenter and completed the questionnaire. A final short interview was conducted. Throughout the study, notes were taken if any issues arose or if participants made relevant comments.

The questionnaire covered several key areas to gauge participants' perceptions and experiences with the XR ad-blocking prototype, followed by semi-structured interviews. First, the questionnaire explored advertisement perception and ad-blocker usage in general, focusing on participants' awareness of advertisements in daily life, their influence on purchasing behavior, and prior experiences with ad-blocking software. Questions also differentiated between the perceived disruption caused by outdoor and digital ads. In the semi-structured interviews, participants were asked to

[16]https://www.lollapalooza.com, last accessed on 2025-02-13.
[16]https://wolt.com, last accessed on 2025-02-13.
[16]https://www.berliner-pilsner.de, last accessed on 2025-02-13.

(a) The aforementioned posters were hung up all around the controlled environment, this being an office floor.



(b) Here, one such advertisement poster is being blocked by a dark grey box overlaid on top of it.

Figure 4: Exemplary pictures of the setup for *the User Experience Study*. Participants were allowed to freely move around the floor and its posters, being able to turn the XR ad-blocker on and off at will.

describe their experience and how much they would potentially use such a device in the future in open-ended questions during the final interview phase. The remaining questions asked about this technology's possible positive and negative impacts on their daily, societal, and work lives.

On average, the study required approximately 30 minutes per participant. This time was distributed as follows: about 10 minutes for the introduction and preliminary questions, 10 minutes for engaging with and exploring the prototype, and an additional 10 minutes for the concluding interview and debriefing.

4.4 Participants of the User Perception Study

A total of 18 people participated in the study, with nine identifying as male and nine as female. Participants age ranged from 24 to 44 years ($\bar{x}$ = 32.28 years, s = 6.2 years). Eight participants were recruited from the vicinity of the experimenter (i.e., family, friends, and work colleagues), and ten further participants were recruited via university mailing lists and snowball sampling.

We explained to all participants that we were interested in their honest assessment. We elaborated that their opinion would not affect the experimenter's personal situation. After the study, participants received 10€ as compensation for their time. At the beginning of the study, the participants were asked whether they had already had experience with head-mounted XR devices, to which eleven responded "Yes" and seven said they had no experience. Participants were informed that their involvement in the study was voluntary and that they could withdraw at any time without any repercussions. We used a pseudonymization list to protect participant responses in the recorded data, enabling them to withdraw their data afterward as well.

4.5 Results of the User Perception Study

The following section outlines the study's findings and provides an overview of the participants' experience with the XR ad-blocking prototype. We outline detailed user perspectives on the essential features and drawbacks of the XR ad-blocking prototype.

4.5.1 Advertisement Perception and Ad-Blocker Usage. The participants' awareness and perceived influence of advertisements in their daily lives were highlighted, with 95% acknowledging outdoor advertising, 60% of whom did so strongly. In contrast, only a small fraction, 5%, disagreed with the statement. Regarding the influence of advertisements on their purchasing decisions and behavior, 90% of participants agreed that ads have an impact, with 25% expressing strong agreement, leaving only 10% in disagreement.

Regarding the use of ad-blockers or payment to remove ads on websites, the study found that 13 out of 18 participants had utilized ad-blocking software on at least one device. Additionally, there was an equal split between participants who had made a one-time payment to remove ads and those who had not, as well as between those currently paying or having paid for ad-removal subscriptions. Perceptions of disturbance by ads varied between outdoor and digital formats; outdoor ads elicited more neutral or disagreeing responses, while digital ads were largely seen as more disruptive, indicating a clear difference in the impact of these two types of advertisements on daily life.

4.5.2 Experience With the XR Ad-Block Prototype. The majority of participants (N=15) agreed or strongly agreed that the prototype helped them stay focused on their surroundings by minimizing the visibility of advertisements. Similarly, all participants found the AR ad-blocker effective at reducing their exposure to real-world ads. The overall user experience was positive, with two-thirds of participants finding it enjoyable. Additionally, only three participants felt the prototype's features were not adequate, a majority

therefore reflecting generally positive feedback on its performance and usability.

Most participants (N=16) agreed or strongly agreed that XR ad-blockers could be valuable for managing intrusive real-world advertising. There was also strong consensus on the potential broader use of the technology to block visual content beyond just advertisements. Moreover, many participants (N=16) believed that XR ad-blockers could enhance their public space experiences by eliminating distracting ads or visual clutter. These results suggest a generally optimistic view of the utility and benefits of XR ad-blockers among the participants.

The data highlighted participants' concerns about missing important information while using an AR ad blocker. Specifically, 60% of respondents agreed, and 20% strongly agreed that they were worried about missing out on information when the ad blocker was active. In contrast, 10% were neutral, and another 10% disagreed.

Furthermore, 35% of respondents disagreed, and 5% strongly disagreed with using an XR ad-blocker regularly. Meanwhile, 10% were neutral about daily use. On the other hand, half of the participants agreed, indicating a considerable interest in using an XR ad-blocker in everyday life. This distribution reflects a mixed level of interest, with significant portions both for and against the idea.

4.5.3 Qualitative Data Analysis. The final questions were asked during semi-structured interviews, and the participants' responses were collected, transcribed verbatim, and reviewed. These responses were then coded by one researcher into relevant categories based on recurring themes and specific mentions using reflexive thematic analysis [6, 8]. The categorization process combined manual analysis with text analysis tools to accurately capture and represent these themes.

Regarding the desired features, participants preferred devices customized to their specific needs, valuing the ability to adjust ad-blocking settings. Comfort and design were important factors, including size, weight, and appearance. They expected reliable performance, with effective ad-blocking and minimal glitches. Privacy and security were major concerns, with a strong desire to protect personal information. Additionally, there was interest in features beyond ad-blocking, like personalized notifications or integration with other useful apps.

When asked what would prevent participants from using an XR ad-blocker, participants were primarily concerned with the device's ability to block ads accurately without interfering with other important content, highlighting the need for precise ad-blocking. Comfort and ease of use were critical, as cumbersome or difficult-to-use devices were less likely to be adopted. Technical issues like glitches, delays, or short battery life were seen as major drawbacks, emphasizing the need for reliable performance. Privacy and data security were top priorities, with concerns about potential breaches being a significant deterrent. Additionally, the financial cost and technical complexity of using and maintaining the device were important factors, as high costs or difficulty in maintenance could limit adoption.

Regarding the expected positive impacts, participants anticipated a significant reduction in their exposure to advertisements, leading to a more enjoyable and less cluttered environment, thereby achieving a decrease in ad exposure. Many participants believed that minimizing ad exposure would enhance their ability to concentrate and focus in personal and professional settings, resulting in better focus and concentration. Some participants suggested that fewer distractions from advertisements could improve social interactions, allowing individuals to be more present and engaged, thereby enhancing social interactions. Some expectations reducing constant advertising exposure could positively impact mental health by lowering stress and overstimulation, providing mental health benefits. Additionally, a few participants pointed out the potential environmental advantages, such as reduced waste and resource consumption due to decreased reliance on physical advertisements, thus contributing to environmental benefits.

5 User Acceptance Study: Gathering Public Perceptions on Potential XR Ad-Blocking Concepts

The findings from the initial **User Perception Study** demonstrated that while participants generally responded positively to the XR ad-blocking prototype, there were key concerns related to usability, privacy, and potential drawbacks, such as missing important information and the complexity of maintaining such devices. Although most participants found the XR ad-blocker effective and valuable for managing intrusive advertising, the mixed feedback on regular use and the desire for customizable features, precise ad-blocking, and improved user experience highlighted the need to explore user preferences further.

Given these results, we conducted the following User Acceptance Study to understand how different design concepts might address these concerns and influence user acceptance. By presenting six distinct XR ad-blocking concepts, this study aimed to evaluate broader user reactions and identify which approaches could enhance adoption and potentially alleviate apprehensions. This study provided valuable insights into user preferences for XR ad-blockers, giving feedback on different visualizations of XR ad-blockers to help during the next steps in developing such technology.

5.1 XR Ad-Blocking Concepts of the User Acceptance Study

The concepts for how the visualization of XR ad-blocking technologies could look were primarily based on the publication "Towards Understanding Diminished Reality" by Cheng et al. [9]. This work has already been presented in Section 2.1, and with it the six different effects of which *(E1) Reduce opacity*, *(E2) Outline*, *(E3) Blur*, and *(E5) Desaturate* have been adopted as is. As *(E4, Reduce Saliency)*, *(E5, Desaturate)*, and *(E6, Reduce Contrast)* are fairly similar in nature, we opted only to develop one of these effects at this stage of research. Furthermore, we add two more concepts, which are based on the viral XR ad-block concept presented in Figure 1 and the idea of replacing the advertisement rather than strictly diminishing it as explained in Section 2.3.

An example of each of the six distinct XR ad-blocking concepts is illustrated in Figure 5. These concepts can be individually described in detail as follows.

(a) Blur

(b) Desaturate

(c) Partial Transparency

(d) Full Transparency

(e) Warning

(f) Art

Figure 5: The different XR ad-blocking concepts presented to the survey participants. To better demonstrate how these concepts might look in the real world, the same scene was always chosen for all of the six mockups. (Original image by John Towner[17])

- **Blur** [See *(E3)* in [10]] In this concept, the advertisement is blurred, making it less perceptible than before. Color and transparency remain unchanged.
- **Desaturate** [See *(E5)* in [10]] Instead of reducing the sharpness through blurring, this concept desaturates the advertisement's colors. To achieve the biggest impact, we opted to fully remove all color saturation to achieve a gray-scale version of the ad.
- **Partial Transparency** [See *(E1)* in [10]] Herein, the advertisement has reduced opacity, allowing the surrounding environment to slightly shine through. In theory, this can be achieved through various approaches, ranging from pre-known imagery to generative AI fill-ins.
- **Full Transparency** [See *(E2)* in [10]] The same approach can logically also be used to make the advertisement fully transported, effectively removing it from the scene altogether. Here, we opted to still show an outline to inform the potential user that something has been removed.
- **Overlay With Warning** [See Figure 1] Instead of diminishing the advertisements in the ways presented before, this concept visually blocks the advertisement with a warning, notifying the user that it has been blocked.
- **Replace With Art** [See Section 2.3 for "Art in Ad Places" campaign] In a similar vein, but taking further inspiration from the campaign as mentioned earlier, the advertisement is replaced by art instead.

[17] https://unsplash.com/photos/gray-landmark-building-UO02gAW3c0c, last accessed on 2025-02-13.

5.2 Setup and Procedure of the User Acceptance Study

The study was conducted online and began with participants consenting to participate voluntarily. After recruitment through Prolific, participants were directed to the survey, which took approximately 12 minutes to complete. The survey included questions designed to gather demographic information and assess user perceptions of the concepts under study. The concepts were presented to the participants in a between-subjects study design, meaning that 20 participants evaluated each concept.

After gathering qualitative first impressions with a short writing task, the participants were instructed to rate the concept that we presented as pictures with corresponding statements that were based on the **UTAUT2** questionnaire [74] on a 5-point Likert scale. The full set of questions is given in Appendix A.1.2.

Afterward, the **Mixed Reality Concerns** questionnaire by Katins et al. [25] was applied to gather a first indication of the potential apprehension of the participants towards such XR ad-blocking concepts. Similarly, these questions are given in Appendix A.1.3.

Finally, seven questions were asked regarding the participants' preferences toward potential triggers of the XR ad-blocker and the temporal and spatial scope of said technologies. This was based on the three characteristics of "**de-augmentation operations**" as defined by Brasier et al. [7]. Appendix A.1.4 lists these questions in detail. This set of questions was asked to assess user preferences regarding control options for blocking different types of advertisements using such an XR ad-blocker. By evaluating this for a total of the six content categories (i.e., generic products, alcoholic beverages, sexually suggestive content, public campaigns that pertain to sexual topics, public campaigns that pertain to cultural events, public campaigns that pertain to issues of public safety) per concept, we aimed to explore how users perceive the need for customization and automation in blocking specific types of ads. The six content categories were selected to represent a balanced mix of commercial advertisements (e.g., generic products, alcoholic beverages) and public campaigns (e.g., cultural events, public safety issues). Additionally, some of these categories, such as sexually suggestive content and public campaigns related to sexual topics, involve similar potentially controversial themes. The different statements address preferences for varying levels of trigger control (i.e., per-ad decisions, manual rules, system-set rules), spatial scope (e.g., per-entity or location-based), and temporal scope (i.e., temporary or permanent).

5.3 Participants of the User Acceptance Study

All 120 participants were recruited via Prolific[18], providing a more representative sample than institute mailing lists or similar methods. Participation was entirely voluntary, with the option to withdraw at any time. Upon completing the survey, participants were compensated £2, which corresponds to an average hourly rate of roughly £10. The participants ranged from 18 to 62 years old, with the average age of participants being around 34 years ($\bar{x} = 34.03$ years, $s = 10.74$ years). 50% of participants identified as male and 50% as female. All participants resided in the United Kingdom, the United States, or Canada.

[18]https://www.prolific.com, last accessed on 2025-02-13.

5.4 Results of the User Acceptance Study

The following analysis of the online survey results gives an overview of which concepts for XR ad-blocking visualizations were most and least preferred by the participants. We provide detailed insights into what seemingly constituted those opinions and how the participants would like to interact with these concepts, taking related work into account.

5.4.1 UTAUT2: Hedonic Motivation Varies Most Between Concepts. The normalized results of the UTAUT2-related questions revealed that participants' ratings varied across the different concepts, though the "Art" concept consistently received higher scores than others. These results are visually represented in Figure 6.

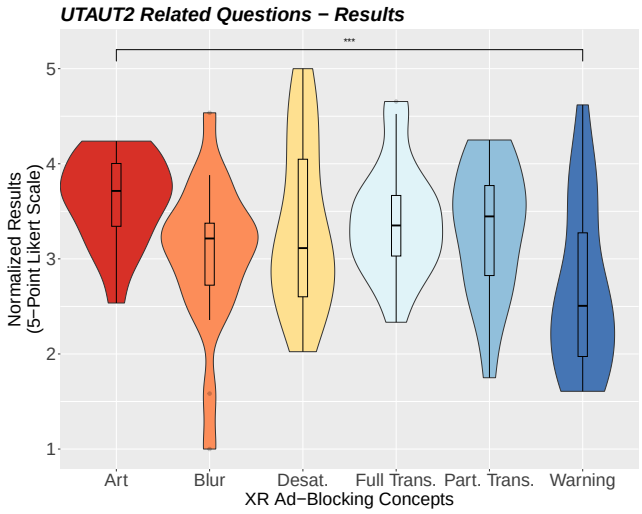


Figure 6: The normalized results of the UTAUT2-related questions show that participants generally rated the concepts on a broad range. Yet, the "Art" concept shows slightly higher scores overall and achieved significantly higher results than the "Warning" concept.

A Kruskal-Wallis test showed statistically significant differences between the concepts ($\chi^2(5) = 17.77, p < 0.01$). Pairwise Wilcoxon rank sum tests, with continuity and p-value Bonferroni correction, revealed that the "Art" concept achieved significantly higher scores than the "Warning" concept ($p < 0.01$).

Further analysis showed that the other UTAUT2 constructs did not reveal significant differences between the concepts. Comparisons involving "Blur," "Desaturation," and different levels of transparency largely failed to produce statistically significant results, indicating that participants rated these concepts similarly across most constructs. However, the "Hedonic Motivation" construct, which measures the enjoyment or pleasure of using technology, stood out with multiple significant differences. The "Art" concept, in particular, scored significantly higher in hedonic motivation compared to several other concepts, most notably the "Warning"

concept ($p < 0.001$). Additionally, "Blur" and "Desaturation" also showed significant differences when compared to "Art" ($p < 0.01$ and $p < 0.05$, respectively). This suggests that while other aspects of the UTAUT2 model did not strongly differentiate between the concepts, the enjoyment and engagement participants anticipated to experience with the "Art" concept was a potential key reason for its higher overall ratings.

Conversely, the "Warning" concept consistently performed worse than the other concepts, particularly in hedonic motivation, where it was significantly lower than most others. Besides the striking difference compared to "Art," the "Warning" concept was also rated significantly lower in hedonic motivation compared to both "Full Transparency" and "Partial Transparency" (both $p < 0.01$). These results indicate that participants found the "Warning" concept less engaging and enjoyable, highlighting the stark contrast between "Warning" and the other concepts. These results for just the "Hedonic Motivation" construct are also shown in Figure 7.

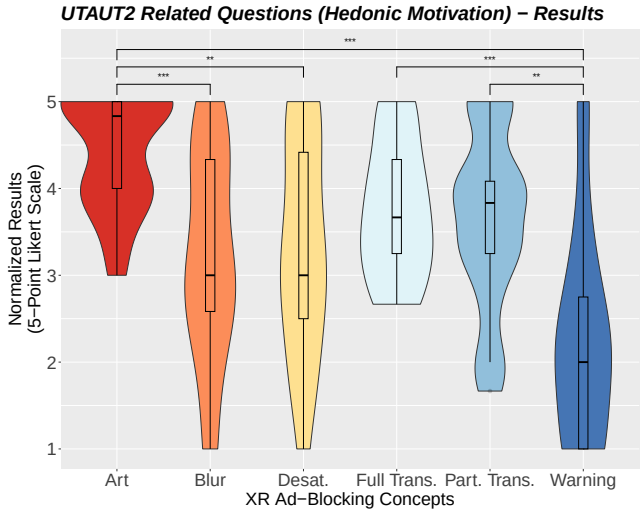


Figure 7: The normalized results of just the "Hedonic Motivation" latent variable of the UTAUT2-related questions show multiple significant differences between the assessment of the XR ad-blocking concepts.

5.4.2 Mixed Reality Concerns: No Significant Differences In Concerns Regarding Concepts. The results for the Mixed Reality Concerns questionnaire section indicate that participants found all concepts to be similarly concerning, with no significant differences in apprehension between them. A Kruskal-Wallis test showed no statistically significant variation across the concepts ($\chi^2(5) = 3.86$, $p > 0.05$), suggesting that participants rated their concerns about each concept in a relatively similar manner. The box plots and distribution of the full-scale MRC questionnaire results are given in Figure 8.

Overall, the participants did not express elevated levels of concern for any particular concept, contrasting with the findings from the User Perception Study, where participants who had the opportunity to test a working prototype exhibited more varied responses.

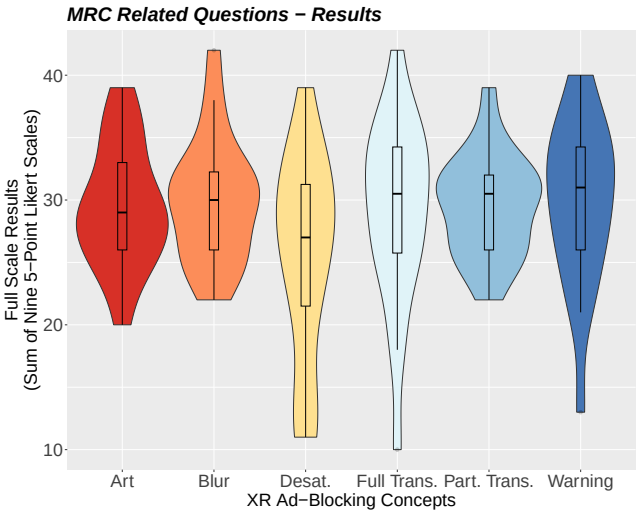


Figure 8: The full-scale results of the MRC questionnaire show no significant differences in the concerns and apprehensions that participants had in regard to the different XR ad-blocking concepts.

5.4.3 De-Augmenting Operations: Context Matters. The seven survey questions focused on how participants might want to use the proposed XR ad-blockers, with higher scores indicating a greater interest in using these XR ad-blocking concepts. The results show that participants' interest in how to operationalize the different ad-blocking concepts varied more significantly across different categories of ads (columns) than between the specific concepts of the ad-blocker (matrices). Figure 9 shows the mean results of the 5-point Likert scale questions. Herein, only the IDs of the questions are given for brevity; the full questions can be found in Appendix A.1.4.

Notably, regardless of whether the question involved manual control (i.e., deciding which ads to block on a per-ad basis) or automatic control, participants expressed less interest in using the ad-blocker for public campaigns compared to other ad categories (as can be seen by the blue tint of these rows throughout all concepts). This suggests that participants were generally more interested in how one might control the XR ad-blocking concepts when in the context of regular commercial advertisements, they were less concerned about these aspects when the ads related to public safety or cultural campaigns.

The results show that participants generally preferred manual control over automatic blocking when using the XR ad-blocker. Both deciding on a per-ad basis (DE2) and pre-selecting which ads to block beforehand (DE3) received higher ratings than automatic blocking (DE4), indicating that participants were more interested in having direct control over the ads that were blocked.

However, the category of "sexually suggestive content" stood out as an exception. Across all concepts, participants expressed the highest level of interest in blocking sexually suggestive content, and herein, automatic blocking (DE4) was much more preferred. This suggests that while manual control is typically favored, participants were more comfortable with automatic blocking when it came to

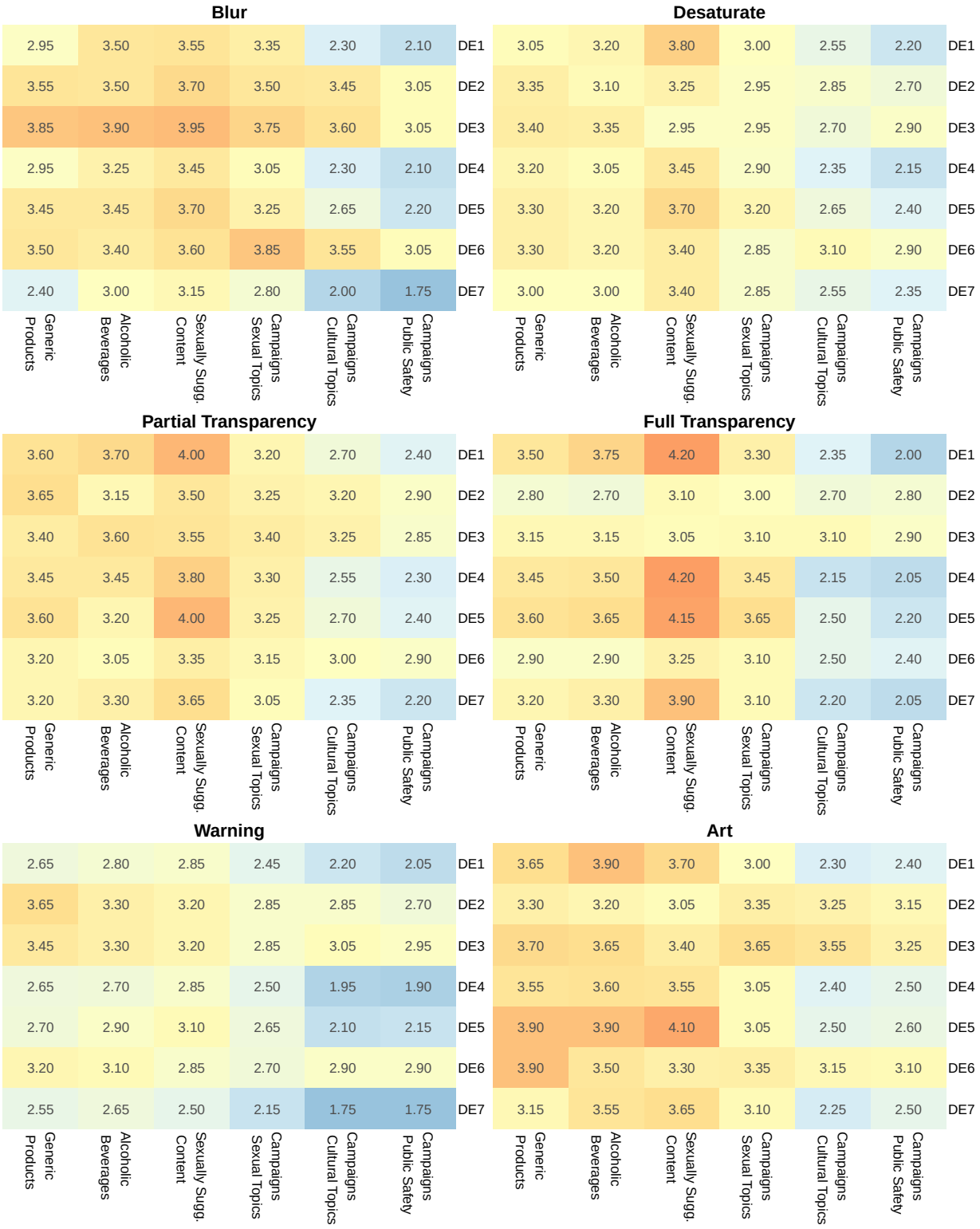


Figure 9: Heatmaps showing participants' agreement regarding the operationalization of the different concepts about the category of content being blocked.

managing more sensitive or potentially inappropriate content like sexually suggestive ads.

The results indicate that participants generally preferred temporary blocking over permanent blocking when using the XR ad-blocker. Temporary blocking (D6) consistently received higher ratings compared to permanent blocking (D7), suggesting a stronger interest in ad-blocking solutions that offer flexibility and adaptability.

6 Discussion

In the following, we discuss the results of both studies and revisit the research questions initially stated in Section 2.

6.1 Revisiting RQ1: How much are users inclined to use XR ad-blockers in real-world advertising contexts?

Participants found the XR ad-blocker prototype effective and beneficial, particularly in reducing visual clutter and enhancing focus. The positive feedback suggests a substantial inclination toward using such technology to manage disruptive advertising in real-world settings, similar to ad-blocking used on the web [55]. This also shows that the participants would like more control over what they perceive, as (public) physical ads are usually placed without the explicit consent of those who perceive them. Wolf et al. argue that this action is ethically reasonable in a public space, as a person "lays claim to the visual space between the [XR device] and up to, but not including the advertisement" [79, p.130]. This observation is also interesting in light of a recent study by Franke et al., indicating that public opinion in the U.S. generally goes towards billboard ads being informative and entertaining, not favoring a ban on billboard ads [17].

The continued results of our user perception study strengthen this. Concerns about missing important information when ads are blocked, and the mixed interest in regular use suggest that while users see the potential benefits of XR ad-blockers, significant considerations could affect their willingness to adopt these tools consistently. The qualitative insights of the semi-structured interviews support this claim. **Participants expressed desires for customization, reliability, and strong privacy protections, indicating that these factors are crucial for broader adoption. Technical issues, potential privacy breaches, and financial costs are barriers that could influence users' inclination to use XR ad-blockers regularly.** These findings overlap to some extent with user perceptions on Web-based ad-blocking [73], and on XR in general [12, 65, 69]. Additionally, the adoption of XR ad-blocking will also be dependent on the technical development of XR devices and their capabilities [48].

In conclusion, while there is a clear interest in XR ad-blockers and recognition of their potential advantages, the results suggest a preference not merely for outright ad-blocking but for greater control over advertisements, with a focus on diminishing their agency and limiting their pervasiveness. Furthermore, the inclination to widely use them is tempered by concerns over functionality, content accuracy, and personal data security. **We propose that researchers and developers should prioritize designing XR ad-blockers that offer customizable ad-filtering options rather than outright ad removal. This could include features like adjusting ad transparency, limiting interaction, or repositioning intrusive ads, addressing user concerns about ad agency while maintaining access to potentially relevant content.**

6.2 Revisiting RQ2: How do users perceive different concepts for XR ad-blocking visualizations?

Users' perceptions of different XR ad-blocking visualization concepts reveal notable preferences and distinctions. The "Art" concept consistently emerged as the most favored, particularly in terms of hedonic motivation, which measures the enjoyment derived from using the technology. This concept outperformed others, such as "Warning," which was rated less favorably in terms of user enjoyment and overall appeal. The "Art" concept's higher ratings suggest that users are drawn to visually appealing and enjoyable ad-blocking solutions. Conversely, the "Warning" concept received consistently lower ratings across several metrics, especially in hedonic motivation. This indicates that users found it less engaging and pleasant compared to other concepts. The statistical analysis revealed significant differences between the "Art" and "Warning" concepts, underscoring the stark contrast in user preference. The results further indicate that the default concept for blocking ads on the Web (i.e., "Full Transparency") is not as appealing for XR users, whereas the concept of replacing ads with other content such as artworks is not widely used in traditional ad-blockers [78]. **These findings also show that projects that replace ads with art, such as "NO-AD" [60] and "The Artvertiser" [47], can indeed serve as inspiration for future XR ad-blockers. This shows relevance to further study XR content blockers, as existing solutions may not directly apply. We propose that researchers and developers ought to explore innovative approaches beyond traditional ad-blocking methods, examining non-academic sources alike.**

Replacing ads with appealing content such as artworks could also have further beneficial implications, e.g., as public art [38] and "cat content" [44] can have a positive impact on people's well-being and mental health. Furthermore, as private taste is a strong factor in which artworks people appreciate [28], future XR ad-blockers should offer people control over which kinds of artworks are placed instead of the ads. Also, from a technical point of view, replacing physical ads with other content instead of making them transparent is more easily feasible, as the XR device, in most cases, likely does not know how the surface behind the ad, e.g., on a physical billboard on the wall of a building, looks like. Thus, the XR ad-blocker would need to estimate what the physical material might look like and generate a virtual overlay, e.g., using generative AI.

Regarding concerns about the XR ad-blocking concepts, the results of the MRC questionnaire showed no significant differences among the various concepts, suggesting that participants had similar levels of apprehension regardless of the ad-blocking visualization approach. A potential reason why participants did not express apprehensions during the online study but did during the hands-on session could be the difference in how the technologies were

experienced. In the online study, participants likely relied on abstract descriptions and hypothetical scenarios, which may not have fully conveyed the immersive or potentially disruptive nature of the concepts. This can lead to more neutral or detached responses. In contrast, the hands-on session allowed participants to engage directly with a working prototype, providing a more tangible and immersive experience. This likely heightened their awareness of the real-world implications, risks, or discomforts associated with the technology, prompting more pronounced concerns during the in-person trial. **We propose that future research and development should prioritize hands-on user testing alongside online studies to capture more accurate user concerns, ensuring that XR ad-blocking solutions address real-world usability and immersion challenges effectively.**

6.3 Revisiting RQ3: How would users operationalize these different concepts regarding different types of advertisement content?

Regarding operational preferences, participants strongly preferred manual control over automatic blocking, particularly when selecting which ads to block on a per-ad basis or pre-selecting ads to block in advance. This preference highlights a general desire for more direct and customizable ad-blocking options. However, when managing sensitive content such as sexually suggestive ads, participants favored automatic blocking, indicating comfort with automatic solutions for handling potentially inappropriate content. Here, future work should take into account different cultural perceptions of which content is considered offensive [68]. Furthermore, the strong preference for manual control for most types of ads highlights the need for intuitive and accessible interfaces that enable users to control their ad-blocking experiences. In Web-based ad-blockers, most users do not change the default settings [78]. **Thus, intuitive controls of XR ad-blockers will need to be researched in the future to enable users to control the ad-blocker beyond the default settings. Yet, developers should take care not to overwhelm users with a too complex control interface, a phenomenon that is well studied, for example, for privacy preferences in mobile [63] and XR apps [1].**

Additionally, temporary blocking options were preferred over permanent blocking, suggesting users value their ad-blocking solutions' flexibility and adaptability. This preference for temporary blocking aligns with a broader interest in dynamic and context-sensitive ad-blocking strategies. Contrary to Web content that is usually consumed individually, the context and bystanders around the user are more important when using XR ad-blockers. Physical ads are especially consumed in social settings where other people might be around the XR user. Depending on who else is present in the same environment, XR users may thus favor different blocking strategies for ads of different content types. Additionally, ad-blocking might introduce information asymmetries [56] between the XR ad-block user and bystanders, which could have a negative impact on their shared social reality. This calls for more research on XR ad-blocking in different social settings.

Overall, the findings indicate that users are more inclined towards XR ad-blocking visualizations that are visually appealing and engaging, offer manual control, and provide temporary blocking options while showing a notable preference for automatic blocking in managing sensitive content. We propose that researchers and developers should focus on designing XR ad-blocking visualizations that balance aesthetics and functionality alike.

6.4 Future Work and Limitations

Future research should focus on conducting longitudinal studies and extensive field trials to better understand XR ad-blockers' real-world implications and user experiences, particularly regarding concerns like missing critical information. For instance, generative AI could be used to subtly adjust or replace blocked content with visually similar, less intrusive alternatives, potentially deceiving users into thinking they are viewing authentic content [26]. Additionally, exploring various ad categories and contextual factors will help refine ad-blocking algorithms and user interfaces while leveraging AI-generated feedback loops that adapt to user behavior in ways that may prioritize engagement over transparency. In this study, we concentrated on blocking physical ads through virtual means. Building on this, future research could investigate user perceptions of content blocking in virtual environments such as VR games compared to hybrid environments such as AR or MR applications. Generative AI might also be used to create highly immersive or personalized ad content that bypasses user detection entirely. Moreover, future research could examine the blocking of virtual compared to physical ads in different environments while also investigating how AI-generated ad variations or replacements impact user trust and awareness in these spaces.

Limitations of this study include the relatively small sample size and the short duration of the trials, which may not fully capture long-term user behaviors and preferences. Furthermore, the online survey may not have fully addressed concerns raised during in-person testing, suggesting a need for more comprehensive evaluation methods. Furthermore, the recruitment of friends, family members, and colleagues in the User Perception Study may introduce unintended power dynamics that could affect participants' sense of voluntariness. Existing literature indicates that power imbalances are inherent in research relationships, especially in participatory community settings [4]. Similarly, research on participatory action methodologies notes that power differentials between researchers and participants are challenging to eliminate and can impact the authenticity of the data collected [35]. In our lab experiment, participants were assured that their decision to participate or withdraw would have no consequences or disadvantages and that all gathered data would be pseudonymized.

We recruited participants from different countries for the two studies, with the first study conducted in Europe and the second study involving participants from North America. This obviously is not a fully representative sample of all potential cultural contexts users and bystanders might have. While we aimed to recruit samples representative of their respective populations to reduce sampling bias and enhance generalizability, herein investigating Western populations, the aforementioned differing attitudes toward

technologies may have influenced the findings. For instance, privacy concerns are generally higher in European populations than in North America [76], which may have led to different levels of feedback and concerns regarding ad-blocking XR technologies, introducing confounding factors. We recognize this limitation and highlight the need for future research to emphasize cross-cultural approaches. This includes our own efforts to enhance the diversity of participant pools in future studies, as well as encouraging other researchers to do the same if applicable.

7 Conclusion

This study comprehensively examines user perceptions and preferences of XR ad-blocking technologies, revealing patterns in how users receive different concepts and features of potential real-world ad-blocking. The research highlights a clear distinction in user inclinations toward ad-blocking visualizations, with the concept of replacing advertisements with naturally appealing content standing out for its higher potential enjoyment compared to other concepts like blurring or desaturating the advertisements. Participants mostly preferred manual control over automatic ad-blocking, favoring options for precise ad selection and pre-configuration. This preference indicates a desire for greater user agency in managing ad exposure. However, the exception of sensitive content, such as sexually suggestive ads, revealed a contrasting inclination towards automatic blocking solutions in these contexts, suggesting a nuanced approach to ad-blocking preferences based on content type. Additionally, the study showed a general preference for temporary blocking over permanent solutions, reflecting users' appreciation for flexible and adaptable ad-blocking options. This flexibility is crucial for accommodating varying ad-related needs and contexts. Conversely, while the fear of missing important information was prominent in the in-person study, they were not reflected in the online survey, highlighting the need for extensive user testing and careful consideration of implementation details in future developments. Our findings suggest that effective XR ad-blocking technologies should prioritize visual appeal, provide manual control options, and incorporate flexible blocking mechanisms. These features align with user preferences and can significantly enhance the adoption and satisfaction of XR ad-blocking solutions. While we focused on XR scenarios where physical ads are blocked using virtual means, the findings of our research can also inform ad-blocking in fully virtual spatial environments such as Social VR or VR games, and the blocking of virtual ads in XR environments. As XR ad-blocking technologies evolve, these insights offer valuable guidance for developers and researchers to create more user-centric ad-blocking solutions that balance control, engagement, and adaptability.

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A Appendix

A.1 User Acceptance Study Questionnaire

In the between-subject survey, each concept was presented to 20 participants, leading to a total of 120 participants. Each participant was presented with a short text description and an exemplary image (see Figure 5 of the concept they were assigned to. After giving consent and demographic information, the following questions were asked:

A.1.1 First Impressions. Please put your first impression of this XR ad-blocking concept into words. What are your first thoughts about it? [Free-Text Field, 50-character answer minimum]

A.1.2 "UTAUT2"-Related Questions. Regarding the presented XR ad-blocking concept, please rate how much you agree with the following statements. [5-Point Likert Scale]

- PE1 I would find this XR ad-blocker useful in my daily life.
- PE3 Using this XR ad-blocker would help me accomplish things more quickly.
- PE4 Using this XR ad-blocker would increase my productivity.
- EE1 Learning how to use this XR ad-blocker would be easy for me.
- EE2 My interaction with this XR ad-blocker would be clear and understandable.
- EE3 I would find this XR ad-blocker easy to use.
- EE4 It would be easy for me to become skillful at using this XR ad-blocker.
- SI1 People who are important to me would think that I should use this XR ad-blocker.
- SI2 People who influence my behavior would think that I should use this XR ad-blocker.
- SI3 People whose opinions I value would prefer that I use this XR ad-blocker.
- FC1 I would have the resources necessary to use this XR ad-blocker.
- FC2 I would have the knowledge necessary to use this XR ad-blocker.
- FC3 This XR ad-blocker would be compatible with other technologies I use.
- FC4 I could get help from others when I would have difficulties using this XR ad-blocker.
- HM1 Using this XR ad-blocker would be fun.
- HM2 Using this XR ad-blocker would be enjoyable.
- HM3 Using this XR ad-blocker would be very entertaining.
- HT1 The use of this XR ad-blocker would become a habit for me.
- HT2 I would become addicted to using this XR ad-blocker.
- HT3 I must use this XR ad-blocker.
- BI1 I intend to use this XR ad-blocker in the future.
- BI2 I would always try to use this XR ad-blocker in my daily life.
- BI3 I plan to use this XR ad-blocker frequently.

A.1.3 "Mixed Reality Concerns"-Related Questions. Regarding the presented XR ad-blocking concept, please rate how much you agree with the following statements. [5-Point Likert Scale]

- SP1 I am concerned about the possibility of non-authenticated individuals gaining access to this XR system.
- SP2 I am concerned about the potential exposure of sensitive data through this XR system to unauthorized parties.
- SP3 I worry that using this XR system might lead to my personal information being misused.
- SI1 I fear that with this XR system, it becomes increasingly hard to maintain a clear distinction between virtual behavior and real-life behavior.

SI2 I am concerned about the potential of this XR system to influence my behaviors in ways that could be detrimental to my well-being.
SI3 Using this XR system might make me appear disconnected from others in my physical environment.
T1 I believe that only legitimate individuals can access this XR system.
T2 I am sure that this XR system is maintaining a secure environment.
T3 I am confident that my anonymity is protected by this XR system.

A.1.4 "De-augmenting Operations"-Related Questions. For the next couple of questions, please consider advertisements for { GENERIC PRODUCTS | ALCOHOLIC BEVERAGES | SEXUALLY SUGGESTIVE CONTENT | PUBLIC CAMPAIGNS THAT PERTAIN TO SEXUAL TOPICS | PUBLIC CAMPAIGNS THAT PERTAIN TO CULTURAL EVENTS | PUBLIC CAMPAIGNS THAT PERTAIN TO ISSUES OF PUBLIC SAFETY }[19] only. Regarding the presented XR blocking concept, please rate how much you agree with the following statements. [5-Point Likert Scale]

DE1 In general, I would like to use the XR ad-blocker to block these kinds of ads.
DE2 I would like to manually decide to block these ads on a per-ad basis.
DE3 I would like to manually decide if the XR ad-blocker should block these ads beforehand.
DE4 I would like the XR ad-blocker to automatically block these ads.
DE5 I would like the XR ad-blocker to block these ads in certain locations automatically.
DE6 I would like the XR ad-blocker to only block these ads temporarily when I decide to.
DE7 I would like the XR ad-blocker to permanently block these ads.

[19]This set of questions was asked for each of the six content categories. This representation is just for conciseness.