From Redirected Navigation to Forced Attention: Uncovering Manipulative and Deceptive Designs in Augmented Reality through Retail Shopping

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Abstract

In the near future ubiquitous Augmented Reality (AR) will see virtual spatial content seamlessly integrated into our everyday lives through fashionable, wearable devices such as AR glasses. In doing so, we will unlock the capacity for multiple stakeholders to augment and personalize our view of reality - not always to the benefit of users. Using speculative design, we explore the risks and repercussions of third party-driven AR-enacted manipulation and deception through the lens of supermarket grocery shopping - an activity where consumers are routinely tracked and exposed to manipulation of attention and purchasing decisions. Through a scenario generation activity, 20 participants (mixing both existing XR users and frequent shoppers) co-created 58 scenarios reflecting on how AR-driven manipulation or deception of shoppers could be enacted. Our **results** show that **(1)** manipulation, rather than deception, is the primary means of affecting consumer behaviour, necessitating we consider AR *Manipulative and Deceptive Designs* (MDDs) more broadly. Moreover **(2)**, we highlight a) how known MDDs can manifest in AR, and b) four novel MDDs that are specific to AR: *Redirected Navigation*, *Directed & Forced Attention Shifts*, *Reality Interference* and *Delayed and Detained*. We reflect on the stakeholders that would manipulate consumer perception of reality, the different manipulations enacted across the lifecycle of consumer shopping, and the AR elements exploited to deliver these ARMDDs, deriving insights into future harms, ethics and safeguarding around ARMDDs to minimize their impact.

Index Terms: ubiquitous augmented reality, deceptive design, grocery shopping, retail shopping, manipulation, attention

1 Introduction

In the near future, Augmented Reality (AR) glasses could become ubiquitous, geared towards consumer adoption [36] and as much an everyday part of user's lives as smartphones are today [28, 17]. A Ubiquitous AR (UAR)-driven application would be able to not only sense and understand the surrounding environment and context [41], but also enable personalized manipulation of our perception of reality [40, 39]. This would offer stakeholders (e.g. AR platforms, application developers) the means towards delivering more targeted personalized advertising [45, 3], manipulating attention [43] and memory [7] and consequently decision making, and even enacting deceptive designs [9, 8] interwoven with our experience of reality [30] to trick users into taking actions that (e.g. economically) benefit said stakeholders - likely to the detriment of the users.

If we consider where such a technology might be exploited first, an obvious choice is that of consumer shopping - an economic activity which is subject to intense stakeholder-driven pressure to direct consumer purchasing [32]. The *science of shopping* [22, 49, 53] has repeatedly noted that the supermarket environment offers perhaps the most commercialised real-world shopping experience - with shoppers being effectively bombarded with both physical and digital [10] marketing/advertising as they traverse the shop, intending to manipulate their attention [11] and influence purchasing decisions on-the-spot [15]; exposed to offers and promotions [18] designed to encourage more purchasing beyond what they intended; navigating an environment whose layout, sights and sounds have been carefully planned to maximize time in store [5]; and tracked longitudinally both digitally through loyalty schemes and customer cards [20], and physically through in-store sensing (e.g. Amazon Go and similar "Just walk-out" shops [27, 55, 25]).

Understanding how AR can be exploited to manipulate or deceive users on behalf of third parties is crucial. By mapping out these potential misuse scenarios, we can inform guidelines and legislation designed to foresee and prevent unethical or unacceptable practices, thereby protecting users before issues arise. Furthermore, we can support the retail sector in adopting AR in ways that are both ethical and responsible. By identifying problematic uses of AR—whether intentional or unintentional—that verge on deception and manipulation, we can inform future initiatives aimed at safeguarding consumers from the misuse of this technology. Ultimately, our efforts will contribute to the growing body of research dedicated to promoting the socially responsible use of augmented and extended reality in everyday life.

Given the existing and extensive manipulation of consumers in real-world shopping environments [22, 49, 53], it is not a significant leap to suggest that stakeholders such as supermarkets will seek to exploit UAR through accompanying apps that purport to enhance the shopping experience of the user, particularly given the economic incentives to supermarkets, much as they currently offer smartphone companion apps that unlock personalized offers and improve the convenience of the shopping and check-out experience. Thus supermarket shopping offers a promising lens through which to examine the use of UAR to manipulate users, which we focus on.

Through a speculative design study inspired by methodology used in recent works around memory manipulation [7] and virtual-physical perceptual manipulation in XR [52], we explore the risks and repercussions of third party-driven AR-enacted manipulation and deception of supermarket shoppers, to understand how borderline unethical activities might be enabled or amplified given everyday, ubiquitous AR. We choose to focus on supermarket grocery shopping as it is an everyday, common economic activity where stakeholders (supermarket chains) could have almost complete control over the physical and digital experience of their shops - with stable, predictable physical environments easing any local-

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ization/mapping concerns, and clearly differentiable products that would be straightforward to identify and track.

We recruited 20 participants to take part in an online speculative design study where pairs of experienced XR users and shoppers would design and refine deceptive or manipulative scenarios targeting UAR-using supermarket shoppers, across three phases of the shopping journey based on the *Attention, Interest, Desire, and Action (AIDA)* model [14]. This resulted in 58 scenarios that we classified and coded, examining the stakeholders involved; the deceptive and manipulative elements and existing and novel patterns envisioned; how AR is exploited to influence shoppers; what common outcomes occur; and how the deceptions or manipulations varied across the different phases of the shopping journey. As a result, we reflect on the need to move from considering *deceptive designs* to broader terminology around *manipulative and deceptive designs*; the role that AR could play in influencing consumer behaviour; and how the insights derived from the supermarket context could be indicative of how UAR could be exploited in other domains.

Research Gap and Research Questions (RQs)

It is unclear how deceptive and manipulative designs may ultimately be enacted using everyday AR in specific contexts. While prior work provides speculative studies on UAR misuse, they have mostly focused on the general use of UAR without specializing in specific use cases [28, 17, 7]. Our work for the first time considers AR-driven manipulation and deceptive design in a specific applied real-world context - grocery shopping, an economic activity which is subject to intense stakeholder-driven pressure to direct consumer purchasing, attention and behaviour. The AR uses we identify can help other researchers explore how AR user behavior may be manipulated in various contexts - from retail to pedestrian navigation - and understand the motivations stakeholders have to exploit perceptual mediation [40]. This directs future research towards ethics and safeguarding against such designs.

We address the following RQs in this work:

1. How could UAR be used to influence consumer shopping behaviour during real-world supermarket shopping? Addressed in Sections 4 and 6.1.
2. Do envisioned AR deceptive designs targeting consumer shopping fit into existing deceptive design classifications? Addressed in Sections 4.2 and 6.2
3. Does the use of AR deceptive designs change over the course of the customer journey? Addressed in Section 5

2 Related Work

2.1 Ubiquitous Augmented Reality (UAR)

UAR is a term used to refer to the pervasive integration of AR into everyday life [28, 17], envisioned commonly as an all-day wearable, fashionable glasses-style form factor [41]. Despite significant progress, AR glasses from the major Extended Reality platforms remain a point of strong rumour (e.g. Meta speculated to unveil their "Orion" glasses in 2024; Apple glasses in 2027), with existing devices having notable limitations in terms of field of view, sensing, and wearability. Consequently, there are few real consumer-oriented applications of UAR that use smart glasses in the wild yet, with those devices that are available focusing more on usage as digital screens for productivity and entertainment (e.g. XREAL glasses or Lenovo ThinkReality). However, artist renditions (e.g. the dystopian "Hyper-Reality" concept illustrating a heavily augmented metaversal reality) and concept visions (e.g. Meta's "Project Aria") illustrate the potential of UAR as applied to daily activities. For example, in the Hyper-Reality video, we see a consumer traverse an augmented supermarket, replete with personalized adverts attached to the shopping cart/trolley, personalized offers on items around them, and even immersive companion characters that appear to try to emotionally manipulate decision making. Given the pervasive access that UAR has to our perception and the ability to "bend" or mediate reality, many studies [40, 41, 2, 28, 24] have highlighted that UAR applications could potentially pose a serious threat to people's physical, financial, and privacy well-being.

2.2 Deceptive Designs (DD)

The first introduction to Deceptive Design was initially done by Brignull, who collected examples of problematic behaviours present on various websites [8]. Such behaviours targeted specific aspects of the customer, usually finances or privacy, in a way that, while still complying with the law, would trick into or discourage people from making a choice. Very often this would directly benefit a company's interests while directly impacting the users but not enough to push them to seek a solution. Highlighting this phenomenon and holding companies accountable has had a positive impact in reducing the impact of these unethical designs in a period where their use was, in fact, legal [9]. Thanks to the growing interest of the community to call for a more "clean" conduct of the Developers' community, several laws have been implemented to attempt to regulate the design of websites and apps and to limit the implementation of deceptive designs [38, 23]. Since the original classification, many other "dark" patterns have been discovered, with classifications being refined by Brignull [9] and the scientific community, e.g. [23, 29, 34]. In this paper, we refer to the latest classification proposed by Gray et al. [23] as a baseline to describe and classify the potential deceptive scenarios that the participants will be producing throughout the study.

2.3 Deceptive Designs in Extended Reality (XRDDs)

Speculative studies have been employed in Extended Reality (XR) to consider a range of possible problems that could arise Virtual Reality and UAR. Studies such as [52, 7, 17, 30] had particular interest in how AR could be exploited for unethical reasons: for example, by manipulating the user's memory [7], or by deliberately provoking the user to be subject to physical harm by manipulating their perception of themselves and their environment [52]. Krauss *et al.* [30] conducted a speculative design study, finding that XR provoked new XRDDs that leveraged unique XR properties - *perception*, *spatiality*, *physical / virtual barriers* causing discrepancies between real and virtual worlds, and *device sensing*, finding relevant patterns in particular around leveraging immersive properties towards *persuading* and emotional manipulation, *directing attention*, *disguising content*, and *requiring a detour*. And Eghtebas et al. [17] found that risks were posed in particular around situating information alongside existing physical objects, altering perception of surrounding environments, and in personalized attention grabbing measures. However, in both works the scenarios were extracted across a range of proposed use cases, rather than examining one high value use case in-depth as in our work.

2.4 Manipulating Consumers' Behaviour Online

Based on an automatic crawling of roughly 11,000 shopping web sites, Mathur et al. found 15 types of deceptive patterns and about 1,200 sites that made use of them [33]. Their analysis methodology suggests that their result is conservative as only text-based user interfaces were examined. Another study involved a systematic content analysis of the top 200 e-commerce websites in the United States by Moser, Schoenebeck and Resnick identified at least four features encouraging impulsive buying in each website [37]. Similarly, Di Geronimo et al. [13] identified deceptive design patterns in 95% of 240 popular Android apps, with an average of seven patterns per app. In a subsequent online study, their participants failed to identify the presence of the five investigated patterns. In a larger study of end-users' perspective, Bongard-Blanchy et al. [6]

surveyed 406 individuals. They found users are generally aware of such patterns and can recognize them, but also identified a need for additional interventions to protect users from the influence of those patterns. Examples of such interventions are detailed in [6]. In a study setup involving a simulated online shopping task [51], Tiemessen, Schraffenberger and Acar investigated the effect of deceptive countdown timers and could show that most participants perceived such a pattern as e.g., immoral, unfair and unethical.

2.5 Manipulating Consumers Behaviour in Reality

Retail science has extensively explored how to adapt the shopping environment to manipulate consumer decisions as they browse. Already in 1982, Milliman proved that slower background music leads to higher time in store and subsequently increased sales in supermarkets while customers did not notice the music specifically [35]. However, according to investigations by Soh et al. [48], this finding is not transferrable to other sectors as they did not observe similar effects in book stores or apparel shops. Leenders, Smidts and El Haji investigated the effect of ambient scent in a supermarket setting and could show that a high scent intensity results in longer time and higher amount of money spent in the store [31]. Several researchers also analyzed the effects of different lightning and color conditions on customers. Bellizzi and Hite for example showed in laboratory studies that a predominately blue shopping environment led to more positive shopping outcomes such as increased purchases or decreased purchase postponements. Babin, Hardesty and Suter confirmed these findings w.r.t. color, but also found out that the effect of lighting may overrule these effects [4]. Eye tracking studies in real supermarkets, such as the one by Gidlöf et al. [21], were able to show that greater visual attention of customers to a product leads to higher sales. Therefore, supermarkets can use factors such as the number of facings, the position on the shelf, etc. to influence purchasing decisions. Otterbring et al. [42] showed that in-store signage can influence customer attention w.r.t. products on the shelf – although an influence on product choice was not shown.

3 Study - AR Manipulation of Shoppers

AR & XR technology offers a rich platform for spatial computing, with headsets being contextually aware and able to mediate our perception of reality. Research has begun to evidence designs that exploit the affordances of XR [30] to both amplify existing DDs, and enact novel DDs. Conversely, there is a long history of manipulation of consumer behaviour both in reality and e-commerce towards economic and privacy harms. We argue that it is inevitable that these two domains will intersect, with AR being used to manipulate consumer shoppers. Consequently, we set out to examine how AR glasses could manipulate supermarket shopper decisions and behaviours through a scenario elicitation study [7, 52].

3.1 Participants

Our recruitment criteria included (i) individuals who shop at least once weekly and (ii) individuals with hands-on experience in VR or AR games and apps, to blend experience with XR technology and its capabilities with lived experience of how consumer shopper behaviour is currently steered. Participants were recruited from local mailing lists and social media. In total, we recruited 20 participants (11 female, 9 male, average age 24.8, Std.Dev. 6.7). Among the 10 XR users, 7 reported being expert users of AR/VR headsets, either by owning a VR device at home for playing videogames or by using AR apps during their education. The remaining 3 reported having used AR/VR at least 2 times in the past. As for the 10 grocery shoppers, they reported, on average, shopping 2 to 3 times a week. The backgrounds of the participants are summarized in Tab. 3 (see supplemental material).

3.2 Procedure and Data Collection

Participants were coupled together to have one XR user and one grocery shopper in each session. A summary of the experimental procedure is provided in Fig. 1.

Introduction. At the beginning of the session, we introduced the study to the participants with a presentation which lasted around 10 minutes. During the presentation, the participants were instructed on the phases of the study, and the definitions of Deceptive Designs with examples of the most common ones taken from [8], as well as what a hypothesized everyday / ubiquitous Augmented Reality could look like. For this, we showed snippets of simulated AR videos which are available online: "Hyper-Reality", an artists rendition of how AR could augment our everyday lives that includes a tour of an augmented supermarket; and "Project Aria", a concept video by Meta outlining their vision for AR. After the presentation, participants were introduced to the collaborative tool (Miro) they would be using during the session (see Sec. 3.4). Participants were given a few minutes to get familiar with the board, after which the study started.

Scenario Creation. Participants were given 10 minutes to individually complete the first part of the template, describing a scenario where shopper behaviour is manipulated using AR, after which they would be asked to exchange what they had written with the other participant for review.

Discussion. Following this, the researcher guided the exchange between the two participants, extracting what each participant thought of the other participant's scenario.

The scenario and discussion phase were repeated a total of three times, one for each phase of the Customer Journey (see Sec. 3.3) - eliciting 6 AR manipulation scenarios per pair. This study was approved by our ethics board.

3.3 Customer Journey

To ensure we covered the use of AR throughout the shopping experience, from entering the store to making a purchasing decision, we divided the study into three phases corresponding to specific stages of the customer journey, based on the *AIDA* model [14] (see Fig. 2 in Appendix D):

1. **Navigation & Attention**: Navigation through the shop and attention toward a range of products.
2. **Interest & Desire**: Favouritism towards one product over other available nearby products; desire to pick-up / purchase items.
3. **Action**: Proceeding to the till/checkout; queueing; purchasing the selected item(s).

The participants were asked to create scenarios for each of these phases, imagining the customer while navigating the shop (i), choosing between products (ii), or completing their purchases (iii).

3.4 Collaborative Board

We designed a collaborative board on MIRO which was accessible online [link] to all the participants, see Fig. 3 in Appendix E for the board design. The board was divided into two parts: *Scenario Creation*, and *Discussion*. The *Scenario Creation area* was divided into three frames, one for each phase of the customer journey. The Scenario Creation template (Fig. 4) aimed to guide the participants in the conception of the scene in which an imaginary customer is subject to an AR Deceptive Design while engaged in navigating the aisles, handling products, and finalising their purchases. The Discussion (Fig. 5) area was divided into six frames, one for each scenario that was created during the previous phase. Each frame contained a template in which the participants were asked to take

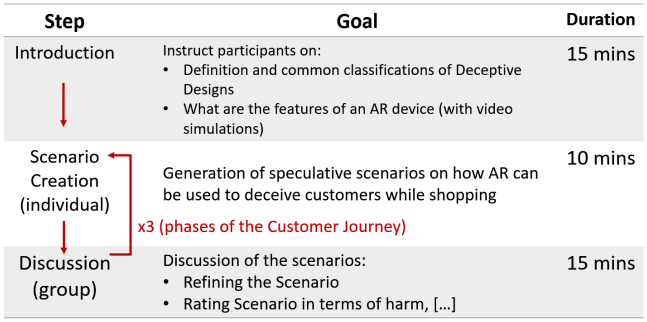

Figure 1: Experimental Flow. The Scenario Creation and Discussion are repeated for a total of three times, corresponding to the three phases of the customer journey.

written notes on their discussion around the perceived likelihood, harms and benefits of the scenario. Finally, the participants were asked to "improve" the scenario to make it more effective.

3.5 Data Analysis

We gathered 58 scenarios (instead of 60, due to technical issues during one of the sessions) and discussion comments and 10 audio transcriptions of discussion. The first phase of the data analysis generated a codebook using the templates in order to extract the important features of the scenarios. Three authors jointly generated the codebook and coded nine (9) scenarios across two sessions, while the first author coded the remaining forty-nine (49) scenarios. The coding process comprised six sessions, each lasting an average of 2.5 hours. Conflicts were resolved through discussions on individual coding instances. During the coding phase, the authors populated the codebook with a mixture of discrete variables (e.g. to flag from a list which AR elements were present in the scenario) and short open answers (e.g. to describe the impact of the deception) which was further refined during a second pass, in which the first author identified common patterns, using thematic analysis.

The repository containing the full data and analysis can be found at `https://doi.org/10.5281/zenodo.12803069` .

4 Results

We examine ARMDDs for grocery shopping across three components: the *stakeholders* that are involved in the deception (Sec. 4.1), the *deceptive or manipulative elements* that are being used to impact shopper behaviour (Sec. 4.2), and the *AR elements* that are being used in the scenario to enact said deception or manipulation (Sec. 4.3). For the sake of brevity, when presenting the results of the coding, we mention the item followed by the number of scenarios that make use of such item in parentheses, in the following way: <item name> (no. of scenarios). The scenarios are referenced by their IDs (e.g., "S1.2" means "Session 1 Scenario 2").

4.1 Stakeholders

4.1.1 The Manipulated Party(s)

The majority of scenarios (52) targeted generic customers, while 6 scenarios focused on *vulnerable* customers, including parents (3) and young people (3). In one scenario (S10.2) , the manipulated party was a small family unit: a mother and her children. This scenario was unique because the manipulation aimed *indirectly* at the parent, utilizing the children as an emotional tool or nagging element to persuade her to purchase what they were asking for.

In 15 scenarios, the manipulated party experienced some form of harm, usually because the app manipulated them into buying expensive or unnecessary things (11), or by subjecting them to a limited field of view, which can cause them to bump into things or other people (6). In 34 scenarios, they experienced both some sort of harm (same as mentioned previously, respectively 17 and 5 scenarios) and some benefit, usually deals (15) or having some sort of entertainment (5). In 1 scenario , they directly benefited from the "manipulation" (see S9.5 for details). Lastly, in 8 scenarios, they neither suffered direct harm nor derived any benefit from the manipulation.

4.1.2 The Manipulator(s)

In 41 scenarios the manipulator was identified as the Supermarket; in 14 scenarios it was the Brand; in 1 scenario it was unclear; in 2 scenarios the manipulator was both the supermarket and the brand; in 1 scenario the main manipulator was a Debt Management Company and the secondary manipulator was the Supermarket. In 8 cases, the manipulator was not clear so it had to be speculated by the coders. The manipulator directly benefited from the manipulation in 56 scenarios and both benefited and experienced some form of financial harm in 2 scenarios, e.g. in case the manipulator had to pay for services to run the manipulation.

4.2 Deceptive and/or Manipulative Elements

Each scenario was coded in relation to which deceptive or manipulative elements were employed. We used the Gray et al. classification [23] for situations that could be linked to a classic DD, and at the same time, we coded the elements that wouldn't fit in or were specific to the domain of ARDDs for grocery shopping. Regarding Gray's classification, the coding highlighted the following:

Interface Interference (46) the majority of the ARMDDs manipulate the user interface (which in the AR case, refers to the interactive elements and visual components that enable users to engage with and control AR applications) to privilege some actions over others. This is usually through monopolising the customer's attention with visual and auditory elements (read section 4.3 for further information on the exploited AR elements).

Obstruction (13) In these scenarios, the ARMDD uses virtual elements to hide certain items, making it difficult for the customer to select a product, for example by hiding them with ads, or with blurred items (e.g. S6.3).

Forced Action (7) the ARMDDs require the user to perform a certain action to proceed with what they were doing, e.g. the app annoys the customer with a nagging sound until they interact with the product being promoted (S9.1), or the navigation service only works if the customer follows the path proposed (S1.1).

Social Engineering (8) Scenarios presented personalized emotional manipulation or social pressure, e.g. by displaying what the customer's friends like to purchase (S7.4) or by leveraging information about the customer's weight to push them to buy "healthier" products (S1.2) . Scenarios also tried to convince the customer to buy specific products through bodyshaming e.g. showing a picture of the customer thinner and healthier if they buy a certain product (S7.6); by exploiting associated vulnerable groups e.g. by using the customer's child, showing them playful augmentations that would encourage them to nag their parent into making a toy purchase (S10.2); and by leveraging emotive stimuli such as joyful or heartbroken avatars to attempt to leverage happiness or guilt to provoke buying decisions (S9.4).

Sneaking (3) In two cases, the ARDDs intent was to hide or disguise information. In one case, by hiding a portion of the metadata regarding a product, in the other case, the app adds items to the cart without the customer's knowledge (S7.5).

Obstruction, Forced Action, Social Engineering and Sneaking designs are usually coupled with the Interface Interference design, except for the cases in which the ARDD does not use any virtual augmentation. See Tab. 4 in the supplemental material for counts of occurrences across patterns and AR element types.

4.2.1 Novel and AR-Specific DDs

We found four new patterns that emerged from the coding:

Redirected Navigation (6) *When the app purposefully forces or tricks the customer to follow a non-optimal path through the physical environment, or otherwise prioritise or avoid certain areas, thus exposing them to additional opportunities for manipulation* [e.g. S3.1]. This can be seen as a more advanced version of *requiring a detour* [30] - as navigation can be directed or dissuaded based on the delivered stimulii. In our supermarket scenarios, this was commonly seen in manipulating navigation towards a desired item to purchase, where the supermarket would e.g. make the customer walk in aisles related to the customer's known habits and preferences in the hope that this could increase the chances that the customer picks up some additional items that they did not originally set out to purchase. This was often enacted using virtual blockades, explicit navigation cues such as arrows, and more discreet environmental changes (e.g. in S5.1 - making parts of the shop grey and others more colourful).

Delayed and Detained (17) *Exploiting controllable delays (e.g. lengthening queuing at the till) to enhance or force exposure to additional stimulii or opportunities for manipulation* [e.g. S9.5]. Where the previous pattern ensured the customer had to navigate more of the environment, this pattern ensures the customer has to spend longer in particular areas. Krauss *et al.* identified *Immersive bait and snap* [30] which tried to leverage immersive content to prolong engagement with experiences, but here we see manipulations intended to prolong engagement with both AR content and the surrounding physical environment. In our scenarios, supermarkets exploited this with the goal of e.g. keeping customers queuing for longer, or spending longer in a particular aisle or section, with the aim that more prolonged exposure to the physical and virtual elements experienced would entice shoppers to make further (or additional last-minute) purchases, similar to how supermarkets currently put small, low-cost items such as sweets next to checkouts. For example, one scenario (S3.2) exploited *Nagging* when leaving a particular section to encourage them to stay longer to consider product options.

Attracted, Directed & Forced Attention Shifts (25) *Where the app leverages gaze fixations and 3D spatial visual and/or auditory cues in the physical environment to attract, direct, maintain, or force attending to specific real-world elements* [e.g. S4.1]. Arguably a form of implicit *forced actions*, and similar to *directing attention* from [30], we found that matching scenarios exploited attention with greater variety than previously discussed in the literature, being the opposite of Grey's *Obstruction* pattern. In the supermarket, this was most often directing or avoiding attention to specific branded items, for example assuming one brand of cereal might augment the user's view to make their brand more visually eye-catching (S1.3).

Reality Interference (15) As an immersive, real-world parallel to *Interface Interference*, these patterns generally leveraged *spatiality* [30], either rendering exocentric AR prompts aligned with/registered to associated real-world elements, or overwriting existing labelling on products. These scenarios would commonly show additional metadata or information about specific objects or items (e.g. S4.4). The manipulation or deception lies in the content of the prompt or alteration, but the pattern is in how this is delivered closely linked/registered to a specific item, interfering with our interpretation of the item in reality. We saw instances where this was used to present time-sensitive deals specific to that item; or overwrite and extend labelling on the product exterior, intended to alter attitudes and preferences toward the product often through seemingly factual, personalized changes to e.g. nutritional information.

4.2.2 Leveraged Customer Information

We then extracted the elements of the deception/manipulation (*"Information about the customer"*) that identified information the AR app would need in order to actuate the deception:

- **Prior information**: shopping history (5), likes (4), dislikes (1), personal information e.g. demographics, friends, etc. (4)
- **Present information**: shopping list (4), shopping cart (6), activity during the shopping experience (1),
- **No prior information** used (36)

4.2.3 Customer Weak Spots

"What did the deception leverage" identified the elements used to push the customer to comply or react in the desired way:

- **Logic Sphere**: In the majority of cases, the ARMDD leverage the customer desire to optimize the time spent in the shop (13), or to save money (14). Less frequently the scenarios use the user's unawareness of the deception to hide certain information from the customer (7)
- **Emotional Sphere**: In the majority of cases, the ARMDDs use a form of emotional manipulation (26) or social pressure (4) to push the customer to act based on feelings of guilt or responsibility, or to follow their desire to conform to the norm.
- **Both**: The ARMDD would leverage the user's confusion (3) on what item to buy to propose a certain item. In one case, the ARMDD tried to generate a subliminal conditioning.

4.2.4 Manipulation or Deception?

"Manipulation vs Deception" aimed to describe whether the scenario produces was manipulative (i.e. the app is trying to persuade the user) or deceptive (the app contains some lies or fake elements).

Manipulation (28). The majority of ARMDDs tried to persuade a customer into taking a certain action. Usually, these scenarios consisted of classic ads, deal notifications or discount proposals.

Deceptive (15). These scenarios contained some elements of lies and deception, usually by either displaying false, incomplete, or misleading information about a product/service. On some other occasions, the app would refuse to work if the customer did not comply with what the app was asking of the customer, forcing them to take a longer route (S1.1).

Both (11). These scenarios would be more complex and integrate both persuasive and deceptive elements. An interesting example, is the scenario in which the products were augmented with emoji faces, that would try to persuade the customer to pick them by displaying emotions (S9.4).

None (4). Scenarios that were considered as not being manipulative nor deceptive, i.e. the customer gets recommendations during check-out time to add related products based on what is in their cart.

4.3 Exploited Augmented Reality Elements

Each scenario was coded in relation to which AR elements were employed. We used Schraffenberger's classification [46] regarding the types of augmentation. In the following, we make note of how many scenarios use each of the mentioned AR elements:

Extended Reality (53) The majority of ARMDDs add virtual elements to the real world. These encompass various elements, including ad banners (23), graphic/textual information about items (11), navigational elements like arrows and maps (6), blurred areas (4), and animated characters (5).

Diminished Reality (0) in no scenario does the ARMDD explicitly remove elements from the real world, despite the applicability of diminished reality to shopping [50]. Instead of removing elements, usually the ARMDD adds some visual element to block out part of the field of view of the customer, which counts as Extended Reality.

Altered Reality (3) only a limited amount of scenario present virtual elements of alteration to the real. In two scenarios, the customer uses some sort of mirroring service that allows them to try on products (hair color dye and makeup), in one scenario the ARDD applies color correction and artificial shadowing to the environment to make some areas of the shop less appealing than others.

Hybrid Reality (0) in no scenario does the ARMDD complete the real world with virtual elements.

Extended Perception (1) only in one scenario, an auditory signal had been accompanied by visual elements to redirect the customer towards the source of the noise (Forced Action).

We then coded for the appearance of the augmentations, specifically: *"Attentional elements"* focusing on whether the augmentation was designed to overtly attract the attention of the customer; *"Interactivity"*, highlighting whether the deception needs any type of interaction from the user, such as following the indications of the app, or actively interact with the interface; *"Location of the augmentation"*, classifying where the augmentation took place, e.g. if it was tied to the user's field of vision or to certain items; and *"Timing of the augmentation"*, classifying its temporal characteristics, e.g. whether it was short and frequent or long and infrequent, etc:

Attentional elements 49 deceptions leveraged attention (46 visually, 3 with both visual and audio elements), 11 did not.

Interactivity 18 deceptions were interactive (of which 10 "active" where the interaction is based upon the user's actions, and 8 "passive" where the interaction is based upon the user's compliance with the app), and 42 were not.

Location on the person (16), on the items (18), in space, e.g. shelves, aisles, till (20), not specified (11).

Timing Continuous (6) vs Intermittent (23), Infrequent (21) vs Frequent (32), Long (6) vs Short (38) vs Medium (8)

4.4 Outcome

Lastly, we coded the consequence of the deception/manipulation in *short* vs *long term* impact and *intended* vs *unintended* impact. Predictably, the coding surfaced that the majority of consequences generated were intended, short-term, negative (62), and positive (40). However, the scenarios also generated a concerning number of negative unintended short-term (30) and long-term (31) consequences.

The majority of intended consequences generated were about **Money or Time**, either negative (39) such as the customer being manipulated into buying more or more expensive things, or into spending more time in the shop; or positive (24), if the customer had been exposed to pertinent deals, or if the app saved the customer time thanks to the navigation service or by booking a slot in a queue. Other common outcomes were impacting health, cognitive load, and customer misinformation.

Health was mainly impacted negatively and unintentionally, both in the short-run (13), by subjecting the customer to safety-critical restrictions of their field of view which could cause them to bump into obstacles and people (8); and as a consequence of the development of unhealthy eating habits. Sometimes this would also lead to food waste, which has been reported as a long-term unintended consequence to the environment (3).

Cognitive load was mainly impacted in the short term, negatively by distracting the customer from their original intent and redirecting them (intended, 6), or by over-stimulating them with adverts and notifications (5). Customer **Misinformation** was mostly caused intentionally (9) in the short term by the app withholding or misrepresenting information about the items, making it difficult for the customer to make comparisons between products.

Annoyance would be a short-term outcome either as a way to frustrate the customer to make a decision (intended, 4) or as a side-effect resulting from overwhelming them with too many ads (intended, 4). Loss of **Personal Information** was highlighted only in three (3) scenarios as a potential problem stemming from a deceptive design that would ask the customer for personal data in exchange for a deal. Interestingly, negative consequences in the emotional sphere would almost always have another unintended long-term consequence, as a result of **Reputational Damage** to the supermarket, brand, or AR platform/device manufacturer, as the customer could potentially decide to not return to that same supermarket or to wear the AR goggles as a result of their frustration (12).

Positive outcomes, aside from the customer having access to deals, were mostly **Entertainment** (7), as the app would keep them busy during queue time, and **Cognitive** (9) relief when the app would help with reminders or making decisions.

5 ARMDDs Across the Customer Journey

If we consider the customer journey, we see distinct differences in the types of ARMDDs applied across these phases, in particular in the approaches used to mediate attention earlier in the journey, and in how designs ramped feedback up as the shopper moved towards final purchasing decisions.

5.1 "Navigation and Attention" Phase

The manipulative designs that were designed for the Navigation and Attention phase of the customer were mostly trying to manipulate the customer's capability to pay attention to the items around them, and this would be carried out either with the use of visual elements or by controlling the customer's course in the shop.

The majority of manipulative scenarios used advertisements (13), of which some used some type of personal information to create targeted ads (5). One example of personalized ads is S1.2 where the app uses the fact that the customer is overweight to promote weight-loss items, by using pop-in ads in the field of vision of the customer. A popular way to control the customer's attention, was to use the *spatiality* of the AR environment to place adverts to partially block out the field of vision of the customer (e.g. S2.2) - *Reality Interference* (20). This sometimes was coupled with *Redirected Navigation* (6) that, with the excuse to help the customer navigating the shop and find an item quickly, would control what the customer would experience and which ads they would be exposed to (S1.1). Additionally, in some scenarios (e.g S3.1) the proposed path would be longer than necessary -*Delayed and Detained* (5)- in the hope that elongating the customer's time in the shop, the probability for them to pick up additional items would raise.

In general, the way the app would try to redirect the user's attention -*Attracted, Directed and Forced Attention Shifts*- were by using visual cues, colorful or animated, which would be placed in the virtual space, e.g. in crowded spots of the aisle or in front of the items, or by attaching them to the customer field of vision, which would make it difficult for the customer to disengage with. In fewer cases, the ads seek to actively distract the customer by partially obstructing their vision, or grasp their attention with a nagging sound.

5.2 "Interest and Desire" Phase

The variety of scenarios associated with this phase is the richest as the end goal of the manipulation can be reached in many different ways. During the "Interest and Desire" phase, the customer is deciding which product to choose, so the strategies were primarily focused on convincing the customer to buy one product over another, by capturing the customer's attention (i) and maintaining it on the targeted item (ii). Some of the attention-grabbing strategies employed in this phase overlap with those utilized in the "Navigation and Attention" phase. The majority of scenarios used advertisements (11). Rather than attracting attention, the goal of the ads was more detail oriented and aimed to convince the customer that a specific item was more convenient than the competitors. This would be achieved sometimes by selective enhancement, or by visual intrusion - interrupting the customer's browsing by inserting visual

elements in the field of vision of the customer (*Reality Interference / Obstruction*). For example, in S7.1, the customer is looking at the shelf of a specific product, browsing for the cheapest option. Before they even have time to look and compare all the prices, an option pops up in front of them showing a *brand* option of that same product on sale or with an attractive discount. One example of selective enhancement is in S10.3 where a high school student is in a toy store browsing for Pokemon cards; the most expensive cards start being animated by the Pokemon emerging from the card. Another common way of using manipulative devices during this phase was to use meta-data to encourage the customers to pick specific items (*Social Engineering*), for example using statistics of other people's buying habits (or even by the customer's friends), such as in S7.3 and S7.4 where customers could see comments or 5 stars ratings next to the products. Alternatively, like in scenarios S4.4 and S5.4, where the app would offer a recommendation service by comparing two or more products, where the data highlighter was biased or deceptively misrepresented.

5.3 "Action" Phase

Scenarios were mostly focused on making use of the waiting time during the queue before paying (*Delayed and Detained*). This would allow the app to leverage the fact that people don't like non-optimised or "dead" time, by providing the user something to do in the hope that this would prompt them to add a last-minute product to the basket. In S5.5, the app would offer the customer to book a spot in line and suggest the customer use the time saved to check a specific section, tailored to their preferences.

The majority of manipulations were deals and offers presented to the customer on the basis of what they have in their cart (*Social Engineering*), like in S2.5 where - as the customer is purchasing a dress - the app offers matching accessories, such as jewellery and shoes, for a discount. Sometimes this would be enforced with emotional manipulation, by nagging the customer with questions such as "Are you sure you don't also need this item?" or "did you mean to buy this other product?". In one case (S7.5) the app would add the matching products to the cart automatically (*Forced Action*), forcing the customer to manually delete them.

In two (2) cases, the AR visors would be used to allow the customer to directly walk out without passing for the checkout, similarly to what happens in "Just walk-out" stores [27]. This would be coupled with hidden fees (*Sneaking*) added to the chart to raise the possibility for the customer to overpay.

5.4 Limitations

We had to include some examples of DDs from [23] to kickstart the discussion with participants. We acknowledge this may have biased the participants in the creation of their scenarios. Additionally, our results are specific to our demographic sample, and further research is needed to explore non-UK populations and different age groups. Moreover, most scenarios depicted an average customer, without considering factors such as age, gender, or background. Only a few included vulnerabilities like age or family status, leading to biased outcomes. Minority groups were not represented, neglecting circumstances that might affect them. Collecting nuanced data is crucial, so we urge researchers to prompt more diverse participants in future work to consider minorities when generating scenarios.

6 Discussion and Future Work

6.1 The Role of AR in Influencing Shopping Behaviour

Across 58 scenarios, we found a breadth of ways (RQ1, see subsection 4.2) by which UAR was envisioned to be able to influence shoppers, including novel ARDDs that expand our understanding of DD classifications (RQ2, see Section 4.2 onwards), with different deceptive and manipulative designs enacted over the course of the customer journey (RQ3, see Section 4.2-5).

6.1.1 Steering Users through Redirected Navigation

Spatial content was repeatedly leveraged to influence how users physically navigated the supermarket space, what we termed *Redirected Navigation*. This was exemplified in various ways - from explicitly drawing paths to follow (puppeteering), to erecting digital barriers that seemingly blocked certain aisles (dissuasion), to digital targets to be navigated to to encourage entering particular aisles (persuasion). Instead of leveraging virtual-physical perceptual manipulations [52], such navigation was effectively incentivised by e.g., providing unique offers or deals if navigation was followed. Where previously supermarkets would optimize their physical layout to encourage general shopping navigation behaviours [5], with AR supermarkets can instead personalize navigation digitally. In knowing you have a sweet tooth, might they encourage a route that repeatedly traverses the sweet and biscuit aisles for example, or choose a route which traverses less travelled aisles to encourage purchasing of more esoteric or pricier products.

6.1.2 Mediating Attention

A recurring theme was the significance of *Attention Shifts* in both the Navigation and Attention, and Interest and Desire phases. In both phases, the technology captures and redirects customer focus to a product. During Navigation and Attention, AR attracts passersby, pulling them towards specific areas like shelves. In the Interest and Desire phase, attention builds interest in a specific item among similar products -similar to concepts such as AuctentionAR [43] - relying on metadata (Reality Interference) to convince customers to choose the targeted product. These attention strategies align with those described by [54], combining stimulus-driven shifts (drawing attention) and goal-driven shifts (motivating interaction). Egenth et al. [16] define "goal-driven" shifts as intentional and "stimulus-driven" shifts as involuntary. In our context, Navigation and Attention uses stimulus-driven shifts with attention-grabbing visuals, while Interest and Desire employs goal-driven shifts with informative prompts, using logic (e.g., healthier product metadata) or emotional manipulation (e.g., sad emoji for neglected products).

6.1.3 Viewing Unavoidable Augmentations

The above also represents a logical extension of prior supermarket research around attention and exploitation of visual cues [26] - where previously the number, position and height of shelf facings would be manipulated to direct attention to e.g., more expensive brands [11], with AR this can again be personalized and enacted digitally, with visual cues tailored to the user. As a real-world parallel to the classic *Interface Interference* DD, *Reality Interference* through AR was frequently used to portray personalized advertising, marketing and item metadata - with much of this content being difficult to avoid attending to to some degree because of the eye-catching nature of the scenarios described, and the egocentric positioning of some content or overwriting of features such as labelling on items. This is arguably unique to AR - unlike with a typical digital display, there is no looking away from egocentric digital content, whilst even exocentric content can be placed in the user's eye-line.

6.1.4 Bestowing Interactivity to the Shopping Experience

Where previously the shopping experience exhibited only limited interactivity (tangible interactions with products, digital interactions with shopping companion apps), here participants noted the potential for AR to bestow interactivity to many aspects of the store experience. From animating a display of toys to entice a parent or child to try them out; to interactively prompting users queueing at the till to both entertain and entice to make purchases of products within reach, to having digital elements react to proximity, attention and engagement - AR offers a means to bewstow interactivity in a way that was not previously possible.

6.1.5 Driving Personalized, Contextual Manipulations

And underpinning all of the above was contextual personalization driven by AI. Scenarios often worked on the basis of assuming modest extensions to existing supermarket tracking of purchasing behaviour to drive augmentations (e.g., product preferences), but scenarios often went further. With more day-to-day knowledge of the user, personalizations could take into account the time of day, the person's own needs (e.g., are they here for a snack or a shop), and their current preferences (e.g., are they dieting?) to adapt the shopping experience as appropriate - in many cases arguably to the benefit of the user as well as the store. Moreover, scenarios resolutely relied on AR sensing to understand where the user was in the store, and what products they were looking at, holding, or placing in their basket - effectively an AR-driven extension of the previously discussed *Amazon Go* concept of the instrumented supermarket.

6.2 Are All Manipulations Deceptive?

Another important outcome resulting from the analysis is the fact, contrary to expectations, that the majority of scenarios produced used mostly manipulation techniques instead of deceptive ones. The difference between manipulation and deception lies in the fact that deception involves misleading or causing someone to believe something false, while manipulation involves influencing someone's thoughts or actions for personal gain. This might be an indication that for the scope of retail and marketing, it is generally much more optimal to focus on influencing customer behaviors instead of resorting to deception. This is probably because the strength of marketing and retail is based on building a solid relationship with the customer and enticing them to return. Moreover, deception (i.e., deliberately misleading consumers) is often illegal in such contexts, as these would typically be described as unfair commercial practices (e.g., protected against by a breadth of legislation in the EU [19], with similar protections evident elsewhere in the world), whereas manipulation (so long as not enacted via fear or pressure) can fall into a gray area of being legally permitted (albeit this is under review in the EU for example [44].

This raises the question: is the nomenclature of "deceptive design" sufficient when referring to such designs? It is hotly contested matter for philosophy as to whether all deceptions are manipulations and vice versa [12], however we would argue that given the focus on manipulation absent any obvious deception in many of our captured scenarios, for AR/XR generally a more appropriate terminology may be *AR/XR Manipulative and/or Deceptive Designs* (**AR/XRMDDs**), which encapsulates the ambiguity seen here.

6.3 How ARMDDs Might be Exploited Elsewhere?

Some core roles of AR in supermarket shopping include supporting navigation, directing attention, and augmenting intelligence. However, our paper shows these capabilities can be exploited, leading to significant economic and privacy risks for users and undermining the integrity of their decision-making. Future research should explore other domains where UAR capabilities might be exploited for ARMDDs. Beyond the supermarket, our experience of semi-public and public spaces could equally be manipulated to look at, or ignore, particular shops, buildings, adverts, streets or even pedestrian routes - perhaps to the benefit of the user or community (e.g., directing users through less travelled parts of a city to encourage footfall in local business' [47]) or their detriment (e.g., wealthier communities or spaces paying to direct pedestrians to their area, reinforcing existing inequalities). And indeed any aspect of our perception of everyday life could be manipulated or altered - from inescapable personalized advertising, to directing or blocking attention to specific brands of items as we encounter them. Further consideration should be given to research that can identify the common archetypes of ARMDDs, and those that are domain specific, such that we can ultimately legislate for their safe, ethical use.

6.4 The Ethics of Consumer-Targeted ARMDDs

Many of the scenarios outlined are ethically questionable, often due to their use of personal data to drive the outlined ARMDDs, which enables designs to operate in the emotional sphere of the customer, leveraging insecurities, social pressure or senses of responsibility. Allowing technology to autonomously generate emotionally manipulative content is deeply problematic. It could lead to traumatic scenarios such as personalized ads using images of deceased family members that follow the customer around the shop. Emotional manipulation may prompt customers to enroll to a credit-debit services, potentially leading to long-term financial problems.

Another key aspect is the potential use of AR glasses as a wearable device to pay by simply walking out of the shop, similar to Amazon Fresh's *"Just walk-out"* stores. This can desensitize customers to spending and obscure the total amount purchased [25]. Given the range of ARMDDs possible, further research into what constitutes not just legal, but *ethical and acceptable* ARMDDs is required. From a legislation perspective, there is a need for policies and legal frameworks that address the ethical, legal, and societal implications of ARMDDs. This includes guidelines for developers, clear allocation of the responsibilities of platforms and developers, and provisions to deter misuse. From a technical standpoint, methods that operate on a platform level were suggested as a viable solution to counter deception in immersive environments [52]. Future work should focus on detecting unexpected, unusual or risky discrepancies between real-world elements and augmentations e.g. a platform-level function could detect and alert the user when labels are overwritten by an AR app. Alternatively, the system could restrict AR apps' access to sensors posing potential misuse risks, or empower users to compare their experiences under varying levels of privacy permissions to better understand how potentially malicious apps manipulate their perception of their surroundings [1].

7 Conclusion

In this paper, we investigated the potential misuse of AR in everyday life, particularly in the context of grocery shopping. We recruited 20 participants from diverse backgrounds, half of whom were AR users and the other half frequent grocery shoppers. They were tasked with envisioning possible deceptive scenarios arising from the use of AR while shopping in a supermarket. Our analysis revealed distinct patterns and objectives of manipulations across different phases of the customer journey, uncovering a variety of techniques that could be employed to deceive customers. One intriguing observation is the utilization of a combination of emotional tactics alongside personalization, resulting in tailored advertisements aimed at individual customers. Additionally, we found that the visual component of AR serves as a potent means to expose customers to various stimuli, including advertisements, navigational cues, and metadata associated with specific products. Moveover, the majority of generated scenarios focused more on manipulation than outright deception. This tendency could be attributed to the importance for supermarkets to cultivate strong relationships with their customers, wherein deception may not be the most effective strategy. Our findings illustrate the risks posed by ARMDDs in a specific domain, exposing users to prospective economic and privacy harms whilst influencing navigation, attention, and decision making, and emphasize the need for further research examining ARMDDs as applied to specific domains/contexts where they are likely to be exploited in the near future.

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References

[1] M. Abraham, M. McGill, and M. Kamis. What you experience is what we collect: User experience based fine-grained permissions for everyday augmented reality. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, CHI '24. Association for Computing Machinery, New York, NY, USA, 2024. doi: 10.1145/3613904.3642668 8

[2] M. Abraham, P. Saeghe, M. McGill, and M. Khamis. Implications of XR on Privacy, Security and Behaviour: Insights from Experts. *ACM International Conference Proceeding Series*, (22), 2022. doi: 10.1145/3546155.3546691 2

[3] S. J. G. Ahn, J. Kim, and J. Kim. The future of advertising research in virtual, augmented, and extended realities. *International Journal of Advertising*, (1), 2023. doi: 10.1080/02650487.2022.2137316 1

[4] B. J. Babin, D. M. Hardesty, and T. A. Suter. Color and shopping intentions: The intervening effect of price fairness and perceived affect. *Journal of Business Research*, 56(7):541–551, 2003. Retailing Research. doi: 10.1016/S0148-2963(01)00246-6 3

[5] J. Baker, M. Levy, and D. Grewal. An experimental approach to making retail store environmental decisions. *Journal of retailing*, (4), 1992. 1, 7

[6] K. Bongard-Blanchy, A. Rossi, S. Rivas, S. Doublet, V. Koenig, and G. Lenzini. "i am definitely manipulated, even when i am aware of it. it's ridiculous!" - dark patterns from the end-user perspective. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference*, DIS '21, p. 763–776. Association for Computing Machinery, New York, NY, USA, 2021. doi: 10.1145/3461778.3462086 2, 3

[7] E. Bonnail, W.-J. Tseng, M. Mcgill, E. Lecolinet, S. Huron, and J. Gugenheimer. Memory Manipulations in Extended Reality. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23-28, 2023, Hamburg, Germany*, 2023. doi: 10.1145/3544548.3580988 1, 2, 3

[8] H. Brignull. Dark Patterns: User Interfaces Designed to Trick People. https://www.old.deceptive.design/, 2010. 1, 2, 3

[9] H. Brignull, M. Leiser, C. Santos, and K. Doshi. Deceptive patterns – user interfaces designed to trick you. https://www.deceptive.design/, 2023. 1, 2

[10] M. Bues, M. Steiner, M. Stafflage, and M. Krafft. How Mobile In-Store Advertising Influences Purchase Intention: Value Drivers and Mediating Effects from a Consumer Perspective. *Psychology & Marketing*, (2), 2017. doi: 10.1002/mar.20981 1

[11] P. Chandon, J. W. Hutchinson, E. T. Bradlow, and S. H. Young. Does In-Store Marketing Work? Effects of the Number and Position of Shelf Facings on Brand Attention and Evaluation at the Point of Purchase. *Journal of Marketing*, (6), 2009. doi: 10.1509/jmkg.73.6.1 1, 7

[12] S. Cohen. Are All Deceptions Manipulative or All Manipulations Deceptive? *Journal of Ethics and Social Philosophy*, (2), 2023. doi: 10.26556/jesp.v25i2.1998 8

[13] L. Di Geronimo, L. Braz, E. Fregnan, F. Palomba, and A. Bacchelli. Ui dark patterns and where to find them: A study on mobile applications and user perception. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, CHI '20, p. 1–14. Association for Computing Machinery, New York, NY, USA, 2020. doi: 10.1145/3313831.3376600 2

[14] C. Doyle. A Dictionary of Marketing. In *A Dictionary of Marketing*. 2011. 2, 3

[15] A. Dulsrud and E. Jacobsen. In-store Marketing as a Mode of Discipline. *Journal of Consumer Policy*, (3), 2009. doi: 10.1007/s10603-009-9104-y 1

[16] H. E. Egeth and S. Yantis. Visual attention: Control, representation, and time course. *Annual review of psychology*, 48(1):269–297, 1997. doi: 10.1146/annurev.psych.48.1.269 7

[17] C. Eghtebas, G. Klinker, S. Boll, and M. Koelle. Co-Speculating on Dark Scenarios and Unintended Consequences of a Ubiquitous(ly) Augmented Reality. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, DIS '23, 2023. doi: 10.1145/3563657.3596073 1, 2

[18] P. B. Ellickson and S. Misra. Supermarket Pricing Strategies. *Marketing Science*, (5), 2008. doi: 10.1287/mksc.1080.0398 1

[19] Y. Europe. Unfair and blacklisted commercial practices, 2023. 8

[20] B. García Gómez, A. M. Gutiérrez Arranz, and J. Gutiérrez Cillán. Drivers of customer likelihood to join grocery retail loyalty programs. An analysis of reward programs and loyalty cards. *Journal of Retailing and Consumer Services*, (5), 2012. doi: 10.1016/j.jretconser.2012.06.004 1

[21] K. Gidlöf, A. Anikin, M. Lingonblad, and A. Wallin. Looking is buying. how visual attention and choice are affected by consumer preferences and properties of the supermarket shelf. *Appetite*, 116:29–38, 2017. doi: 10.1016/j.appet.2017.04.020 3

[22] P. Graves. *Consumerology, New Edition: The Truth about Consumers and the Psychology of Shopping*. 2013. 1

[23] C. M. Gray and T. Mildner. An Ontology of Dark Patterns: Foundations, Definitions, and a Structure for Transdisciplinary Action. 2023. doi: 10.1145/nnnnnnn.nnnnnnn 2, 4, 7

[24] J. Gugenheimer, W. J. Tseng, A. H. Mhaidli, J. O. Rixen, M. McGill, M. Nebeling, M. Khamis, F. Schaub, and S. Das. Novel Challenges of Safety, Security and Privacy in Extended Reality. *Conference on Human Factors in Computing Systems - Proceedings*, 4 2022. doi: 10.1145/3491101.3503741 2

[25] J. Huberman. Amazon Go, surveillance capitalism, and the ideology of convenience. *Economic Anthropology*, (2), 2021. doi: 10.1002/sea2.12211 1, 8

[26] P. Huddleston, M. T. Coveyou, and B. K. Behe. Visual cues during shoppers' journeys: An exploratory paper. *Journal of Retailing and Consumer Services*, 2023. doi: 10.1016/j.jretconser.2023.103330 7

[27] B. Ives, K. Cossick, and D. Adams. Amazon Go: Disrupting retail? *Journal of Information Technology Teaching Cases*, (1), 2019. doi: 10.1177/2043886918819092 1, 7

[28] R. Johnstone, N. McDonnell, and J. R. Williamson. When Virtuality Surpasses Reality: Possible Futures of Ubiquitous XR. *Conference on Human Factors in Computing Systems - Proceedings*, 2022. doi: 10.1145/3491101.3516396 1, 2

[29] T. Kollmer and A. Eckhardt. Dark Patterns: Conceptualization and Future Research Directions. *Business and Information Systems Engineering*, pp. 1–8, 12 2022. doi: 10.1007/S12599-022-00783-7/TABLES/3 2

[30] V. Krauss, P. Saeghe, A. Boden, M. Khamis, M. Mcgill, J. Gugenheimer, and M. Nebeling. What Makes XR Dark? Examining Emerging Dark Patterns in Augmented and Virtual Reality through Expert Co-Design, 2023. doi: 10.1145/3660340 1, 2, 3, 5

[31] M. A. Leenders, A. Smidts, and A. E. Haji. Ambient scent as a mood inducer in supermarkets: The role of scent intensity and time-pressure of shoppers. *Journal of Retailing and Consumer Services*, 48:270–280, 2019. doi: 10.1016/j.jretconser.2016.05.007 3

[32] A. Lincoln. Retail Manipulation: How to Buy More. 1

[33] A. Mathur, G. Acar, M. J. Friedman, E. Lucherini, J. Mayer, M. Chetty, and A. Narayanan. Dark patterns at scale: Findings from a crawl of 11k shopping websites. *Proceedings of the ACM on Human-Computer Interaction*, 3(CSCW):1–32, 2019. doi: 10.1145/3359183 2

[34] A. Mathur, J. Mayer, and M. Kshirsagar. What Makes a Dark Pattern... Dark? Design Attributes, Normative Considerations, and Measurement Methods. *ACM Reference Format*, 2021. doi: 10.1145/3411764.3445610 2

[35] R. E. Milliman. Using background music to affect the behavior of supermarket shoppers. *Journal of marketing*, 46(3):86–91, 1982. doi: 10.2307/1251706 3

[36] T. T. Minh Tran, S. Brown, O. Weidlich, M. Billinghurst, and C. Parker. Wearable Augmented Reality: Research Trends and Future Directions from Three Major Venues. *IEEE Transactions on Visualization and Computer Graphics*, (11), 2023. doi: 10.1109/TVCG.2023.3320231 1

[37] C. Moser, S. Y. Schoenebeck, and P. Resnick. Impulse buying: Design practices and consumer needs. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, p. 1–15. Association for Computing Machinery, New York, NY, USA, 2019. doi: 10.1145/3290605.3300472 2

[38] I. Obi, C. M. Gray, S. S. Chivukula, J.-N. Duane, J. Johns, M. Will,

Z. Li, and T. Carlock. Let's Talk About Socio-Technical Angst: Tracing the History and Evolution of Dark Patterns on Twitter from 2010-2021, July 2022. arXiv:2207.10563 [cs]. doi: 10.48550/arXiv.2207.10563 2

[39] J. O'Hagan, Gugenheimer, F. Mathis, J. Bonner, R. Jones, and M. McGill. A Viewpoint on the Societal Impact of Everyday Augmented Reality, and the Need for Perceptual Human Rights, 2024. 1

[40] J. O'Hagan, J. Gugenheimer, J. Bonner, F. Mathis, and M. McGill. Augmenting People, Places & Media: The Societal Harms Posed by Everyday Augmented Reality, and the Case for Perceptual Human Rights. In *Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia*, MUM '23, 2023. doi: 10.1145/3626705.3627782 1, 2

[41] J. O'Hagan, P. Saeghe, J. Gugenheimer, D. Medeiros, K. Marky, M. Khamis, and M. Mcgill. Privacy-Enhancing Technology and Everyday Augmented Reality. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, (4), 2023. doi: 10.1145/3569501 1, 2

[42] T. Otterbring, E. Wästlund, A. Gustafsson, and P. Shams. Vision (im)possible? the effects of in-store signage on customers' visual attention. *Journal of Retailing and Consumer Services*, 21(5):676–684, 2014. doi: 10.1016/j.jretconser.2014.05.002 3

[43] A. Pandjaitan, J. Strecker, K. Bektaş, and S. Mayer. AuctentionAR-Auctioning Off Visual Attention in Mixed Reality. In *Extended Abstracts of the 2024 CHI Conference on Human Factors in Computing Systems*, 2024. doi: 10.1145/3613905.3650941 1, 7

[44] D. Reynders. Consumer protection: Manipulative online practices found on 148 out of 399 online shops screened, 2023. 8

[45] N. Sadamali Jayawardena, P. Thaichon, S. Quach, A. Razzaq, and A. Behl. 'The persuasion effects of virtual reality (VR) and augmented reality (AR) video advertisements: A conceptual review'. *Journal of Business Research*, 2023. doi: 10.1016/j.jbusres.2023.113739 1

[46] H. K. Schraffenberger. *Arguably Augmented Reality : Relationships between the Virtual and the Real*. PhD thesis, Leiden University, 2018. 5

[47] P. Siriaraya, Y. Wang, Y. Zhang, S. Wakamiya, P. Jeszenszky, Y. Kawai, and A. Jatowt. Beyond the Shortest Route: A Survey on Quality-Aware Route Navigation for Pedestrians. *IEEE Access*, 2020. doi: 10.1109/ACCESS.2020.3011924 8

[48] K. L. Soh, K. Jayaraman, L.-P. Choo, and S. Kiumarsi. The impact of background music on the duration of consumer stay at stores: An empirical study in malaysia. *International Journal of Biological Sciences*, 16:247, 2017. 3

[49] H. Sorensen. *Inside the Mind of the Shopper: The Science of Retailing*. 2016. 1

[50] J. R. Strecker, J. Wu, K. Bektas, C. Vaslin, S. Mayer, J. Wu, K. Bektas, C. Vaslin, and S. Mayer. ShoppingCoach: Using Diminished Reality to Prevent Unhealthy Food Choices in an Offline Supermarket Scenario. 2024. 5

[51] J. Tiemessen, H. Schraffenberger, and G. Acar. The time is ticking: The effect of limited time discounts on consumers' buying behavior and experience. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI EA '23. Association for Computing Machinery, New York, NY, USA, 2023. doi: 10.1145/3544549.3585735 3

[52] W.-J. Tseng, E. Bonnail, M. McGill, M. Khamis, E. Lecolinet, S. Huron, and J. Gugenheimer. The Dark Side of Perceptual Manipulations in Virtual Reality. In *CHI Conference on Human Factors in Computing Systems*, CHI '22, 2022. doi: 10.1145/3491102.3517728 1, 2, 3, 7, 8

[53] P. Underhill. *Why We Buy: The Science of Shopping–Updated and Revised for the Internet, the Global Consumer, and Beyond*. 2009. 1

[54] M. Wang, S. Boring, and S. Greenberg. Proxemic peddler: A public advertising display that captures and preserves the attention of a passerby. In *Proceedings of the 2012 International Symposium on Pervasive Displays*, PerDis '12, 2012. doi: 10.1145/2307798.2307801 7

[55] K. Wankhede, B. Wukkadada, and V. Nadar. Just Walk-Out Technology and its Challenges: A Case of Amazon Go. In *2018 International Conference on Inventive Research in Computing Applications (ICIRCA)*, 2018. doi: 10.1109/ICIRCA.2018.8597403 1

A SUMMARY OF IMPACT ELEMENTS

Table 1: Short descriptions of the 58 scenarios created by our participants

Scenario ID	Scenario name	Description
S1.1	Searching for a soya milk	Lead customer to promoted item using a navigation style that resembles treasure hunt.
S1.2	Buying food from your to-do list	Pop-in ad generated to divert user from intended purchase, using personal information (e.g. weight) to redirect the user toward a more expensive item
S1.3	Choosing between cereals	App tries to persuade customer to buy a family-pack by displaying a video advert of a family having breakfast as soon as the customer interacts with the item.
S1.4	Pepsi over Coca-Cola	App plays adverts in the field of vision of the customer while he's checking his social media. The ads are related to the items the customer is interacting with.
S1.5	Adding more items	App provides a makeup try-on virtual service during queue time. The mirrored augmentation does not reflect reality.
S1.6	Waiting in line at the cashier	App shows last minutes deals while the customer is in the queue
S2.1	Women shopping for household items	The app places adverts strategically in space to hide cheap products while contextually promoting branded products.
S2.2	Customer is trying to make a normal purchase	The app places very big ads in the field of vision of the customer to frustrate them when they are trying to interact with a non-promoted item.
S2.3	Shopping for cereal	The app presents a list of pros and cons of two items to "help" the customer compare them.However, the list may be misleading/biased.
S2.4	Buyer interested in a book	The app adds both the items the customer is holding into the virtual cart without notifying the customer. (No augmentation used in this scenario.)
S2.5	Extra items	The app shows targeted adverts at checkout that might fit well with the items the customer is purchasing.
S2.6	User wants to remove an item from their cart but is given a warning	When the customer wants to remove an item from the cart, a big annoying pop-up appears indicating that the customer has to now restart the app and re-scan all the items the customer wishes to keep. The app refuses to function otherwise.
S3.1	The longer route	The navigation app forces customer to follow a mandatory long path of the shop, exposing them to more items and adverts, to increase the chances that the customer might pick something on the way.
S3.2	Hey you forgot something!	Nagging adverts are shown when a customer passes by an area where they did not pick anything from.
S3.3	Paid ads	The app displays ads of promoted items when the customer is trying to decide between different brands of the same product.
S3.4	Statistic ads	The customer is presented with statistics and ratings when considering which product to buy. The data shown might be biased.
S3.5	Forced membership	The customer gets forced to have a membership in order to benefit from the quick pay service at checkout. (no AR used)
S3.6	Hidden prices	The AR visor is used to scan the items and pay automatically at checkout, but hidden prices might be paid without knowledge as the final price is not shown, and it is possible that the customer scans things by mistake and doesn't realize it. (AR not used)
S4.1	Being distracted by new offers	A bright and big advert is placed disruptively on the way of the customer, in order to attract attention.
S4.2	Pop-up notification for discounts or promotional items	The customer is surrounded by many pop-ups of promoted items and flash discounts.
S4.3	Cool-looking chocolate	The customer sees adverts while navigating the shop. The promoted items have bigger and brighter adverts.
S4.4	Displaying items as "better", "healthier" or "cheaper"	The app shows info that "helps" the customer comparing between two or more products, however the text uses biasing words such as "better", "healthier", or "cheaper" on the promoted item.
S4.5	How tall	While queuing, the customer is offered a free bakery item in exchange for personal information. The customer is pressured to accept due to time constraints.
S4.6	Promote payment with the pay-later program	While queueing, the customer is asked if they want to subscribe to a pay-later service, in exchange of personal information (no AR used)

Table 2: [*continue from previous page*] Short descriptions of the 58 scenarios created by our participants

Scenario ID	Scenario name	Description
S5.1	Fixed path	The navigation system restricts the customer's exploration and encourage customers to purchase from certain brands, by highlighting only certain aisles and obscuring other parts of the shop.
S5.2	Sales signs distractions	The customer is surrounded by big bright red sale signs.
S5.3	Emotional desire / control	The app shows emojis on top of each product. The promoted products have happy emojis, while the others have sad or neutral emojis. The customer might be biased and be inclined to pick the products associated with happy emojis.
S5.4	Bias information	The app "helps" the customer comparing two products by displaying a summary table, however the comparison is biased to favor the promoted item.
S5.5	AR game	The customer participates in a game while waiting in line. This game is centered around spending money at the checkout. The objective is to ensure that the participant doesn't perceive their action as simply spending money, but rather as completing a game.
S5.6	Membership pressure	The app offers membership to customer while waiting in line, in exchange for personal data. Customer can access exclusive deals only with the membership. The customer is persuaded to accept due to time constraints.
S6.1	Searching a product in the store	The navigation app guides the customer along a suboptimal and lengthier route, thereby increasing the likelihood that the customer will select more items. This is achieved by prolonging the time spent navigating the shop and planning the route based on past purchases.
S6.2	Shopping for vegetables	The customer is surrounded by adverts that try to catch their attention with auditory stimuli or flash deals.The app follows the customer's gaze.
S6.3	Distracting advert on the product	While the customer is holding an item, the app plays ads directly on the item partially blocking out some ingredients or information.
S6.4	Blurring	The app strategically blurs out part of the field of vision of the customer to avoid them noticing certain products and to redirect the focus only on promoted items.
S6.5	Offers and discount during check-out	The app shows discounts and promotions during checkout time.
S6.6	Add on's	The app shows targeted adverts at checkout that might fit well with the items the customer is purchasing.
S7.1	Checking/browsing for the best prices	The customer is looking at the shelf of a specific product, browsing for the cheapest option. Before they even have time to look and compare all the prices, an option pops up in front of them, showing a branded option of that same product on sale or with an attractive discount.
S7.2	Non intended places	The app guides the customer to areas of the shop that they usually don't visit, using colored arrows and highlighting the areas with bright colors. At the same time, other parts of the shop appear grey and narrower to discourage the user from navigating in those areas.
S7.3	Ghost ratings	The app "helps" the customer choose between two items by displaying the "verified customer" star rating of each product. However, the data might be misleading or inaccurate.
S7.4	Best comments	The app "helps" the customer choose between two items by displaying some textual rating of each product. However, the data might be misleading or inaccurate (showing only positive comments for promoted items and neutral or negative comments for other items). The customer also sees the comments their friends left.
S7.5	Surprise add-on	The app automatically adds items to the customer's basket that "go well together" with something already in the customer's cart (e.g., adds salsa if the customer selects tortilla chips). Customers must manually remove the extra items from their cart if they don't want the 'bundle', which is time-consuming and annoying.
S7.6	Buying time	While the customer is approaching the checkout area, pop-ups keep asking them whether they remembered to buy everything and inquire if they are really sure they don't want to add anything else to their basket. Sometimes, the app adds an AI-generated picture of the customer happily holding the suggested product. The aim is to convince the customer to return to the aisles and spend more time there.

Table 2: [*continue from previous page*] Short descriptions of the 58 scenarios created by our participants

Scenario ID	Scenario name	Description
S8.1	Greedy shopper	The app presents the customer with a discount.
S8.2	Sponsored product for cashback	While the customer is observing and comparing various products, they see a colored pop-up on top of the promoted item that offers cashback money if customer signs up for branded company.
S8.3	Average price trap	The customer who wants to buy an item sees an advertisement offering a bundle deal.
S8.4	The Maze	The navigation app guides customers using a non-optimal long path through the shop, exposing them to more items and advertisements, to increase the chances that the customer might pick something up along the way.
S8.5	- Omitted due to technical issues -	
S8.6	- Omitted due to technical issues -	
S9.1	Annoying ping	The app emits a loud ping noise as the customer approaches an area with a product on sale. The product is also highlighted with visual cues. The pinging sound continues until the customer picks up the product. This function can only be disabled in the device settings, which not everyone may know how to do.
S9.2	”Helpful” pop up	As the customer navigates around the supermarket, various pop-ups may be presented to them, either as a prompt in the middle of their vision or more subtly as prompts that pop up next to products. These prompts contain messages recommending the customer to buy certain items based on their shopping habits and history, sometimes even reminding them when they last purchased a certain product.
S9.3	Positive pop-up message	When the customer is choosing between two items, a pop-up message appears notifying the customer of all the positive qualities of a promoted item, aiming to influence their choice. However, the information shown might be biased or misleading.
S9.4	Sad cornflakes	When the customer picks up an item, the app animates the product with a happy animation, viceversa, when the customer puts the product back on the shelf, the animation becomes sad.
S9.5	Book a spot in line	When the customer is approaching the till, the app notifies them of how many people are queueing, offering to book them a slot in the queue. During the wait, the app suggests the customer visit an area of the shop (based on customer habits).
S9.6	Special pricing	The app presents the total price using membership discounts, even if the customer doesn’t qualify for these benefits. Subsequently, the app proposes an express checkout service, potentially leading the customer to unknowingly pay more than anticipated.
S10.1	Buy one get one	The app shows the customer a pop-up promotion when the customer interacts with an item
S10.2	Child shopping with parents	A customer is shopping with their children. The app engages the children with interactive animations featuring toys and other children’s items, fostering a magical atmosphere. The children become so captivated that they begin urging their parent to buy the toys.
S10.3	Toy shopping	A customer is deciding which Pokémon card to buy. The most expensive card suddenly becomes animated with a realistic Pokémon that emerges from the card
S10.4	Cosmetic products	The app offers the customer a virtual try-on service, allowing them to quickly compare two beauty products (e.g., hair dye) by trying them on. However, the mirrored image does not reflect reality, as it is selectively enhanced with AI-generated elements.
S10.5	Socks shopping	A virtual avatar suggests additional items at checkout based on the customer’s current purchases.
S10.6	Debt-free	While paying, the AR goggles detect signs of anxiety in the customer by tracking their eyes. A virtual avatar then attempts to persuade the customer to consider trying the supermarket’s branded support for debts/credits.

B Additional Participant Demographics

Table 3: Participants' academic background. The "S." column represents the Session number.

S.	Grocery Shopper	VR/AR user
01	Marketing	Geography MA
02	Archaeology	Software Engineering
03	Sustainable Energy	Software Engineering
04	Medicine	MSc Financial Technology
05	Mechanical Engineering	Engineering
06	MSc in Data Science	Medicine
07	Creative Industries MSc	HCI / VR
08	MSc Behavioural Science	Computing Science
09	Psychology and French	Computing Science
10	Accounting	Research methods in Education

C Additional Info on Deceptive and/or Manipulative Elements

Table 4: Number of scenarios utilizing Deceptive Designs (rows) and AR elements (columns). An asterisk indicates that the AR element is coupled with an Extended Reality element, and that both refer to the same scenario.

	Extended Reality	Altered Reality	Extended Perception
Interface Interference (46)	45	1*+ 1	1*
Obstruction (13)	13		
Forced Action (6)	6		1*
Social Engineering (8)	7	1	
Sneaking (3)	3		

D Customer Journey

Figure 2: Customer Journey phases, adapted from the AIDA model.

E MIRO BOARD

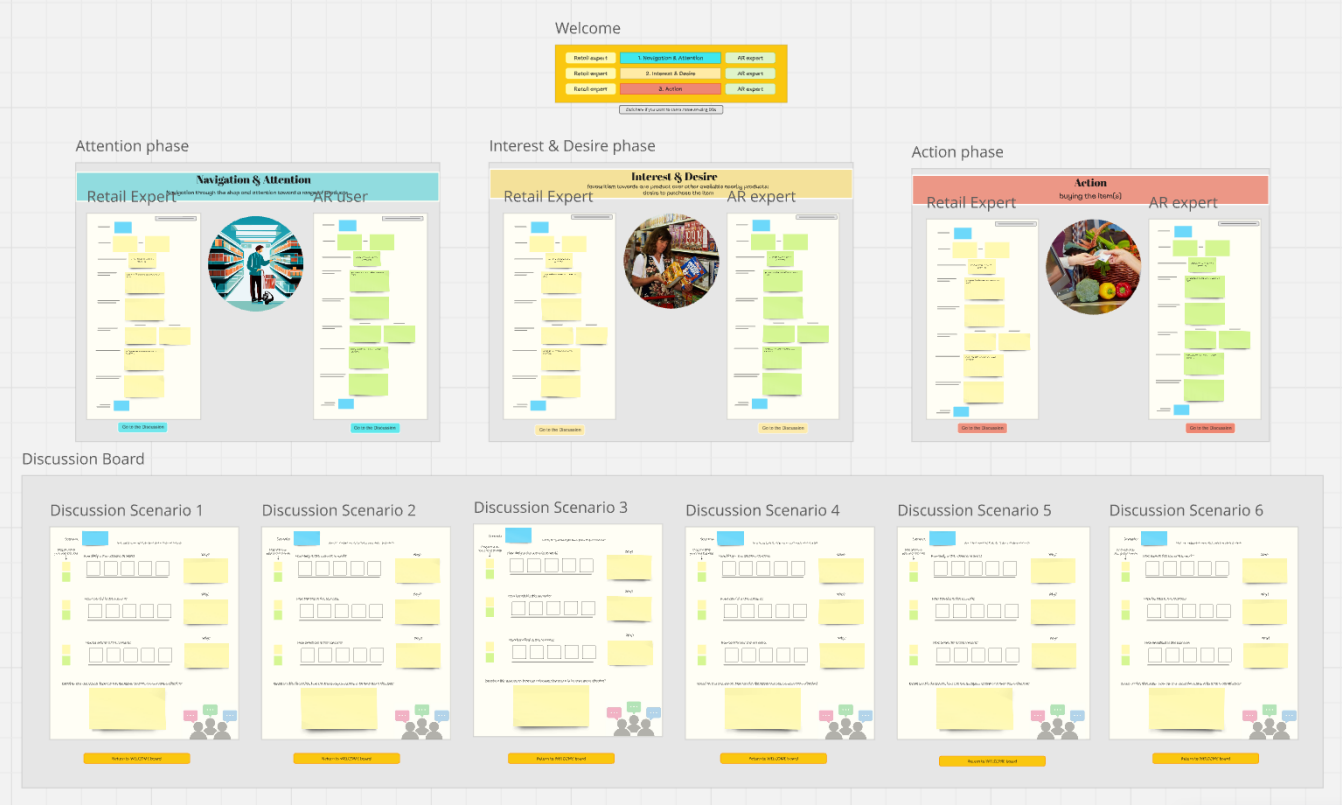

Figure 3: MIRO Project Overview. First row: Welcome area with navigation buttons to assist participants. Second row: Scenario creation templates divided by Customer Journey phase (yellow for grocery shopper and green for AR user). Third row: Discussion templates.
Link: https://miro.com/app/board/uXjVM23rRP8=/?share_link_id=82923580188

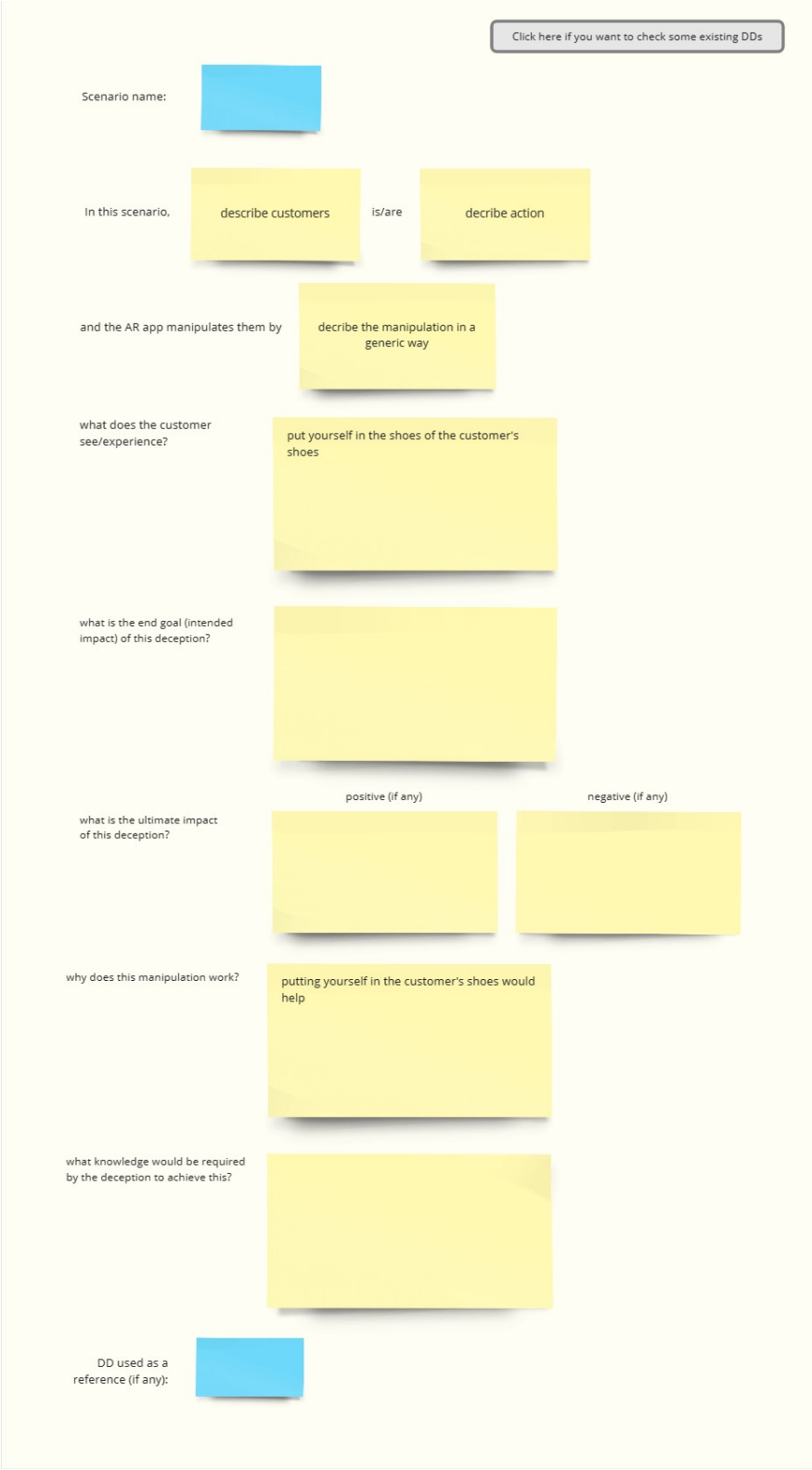

Figure 4: Scenario creation board.

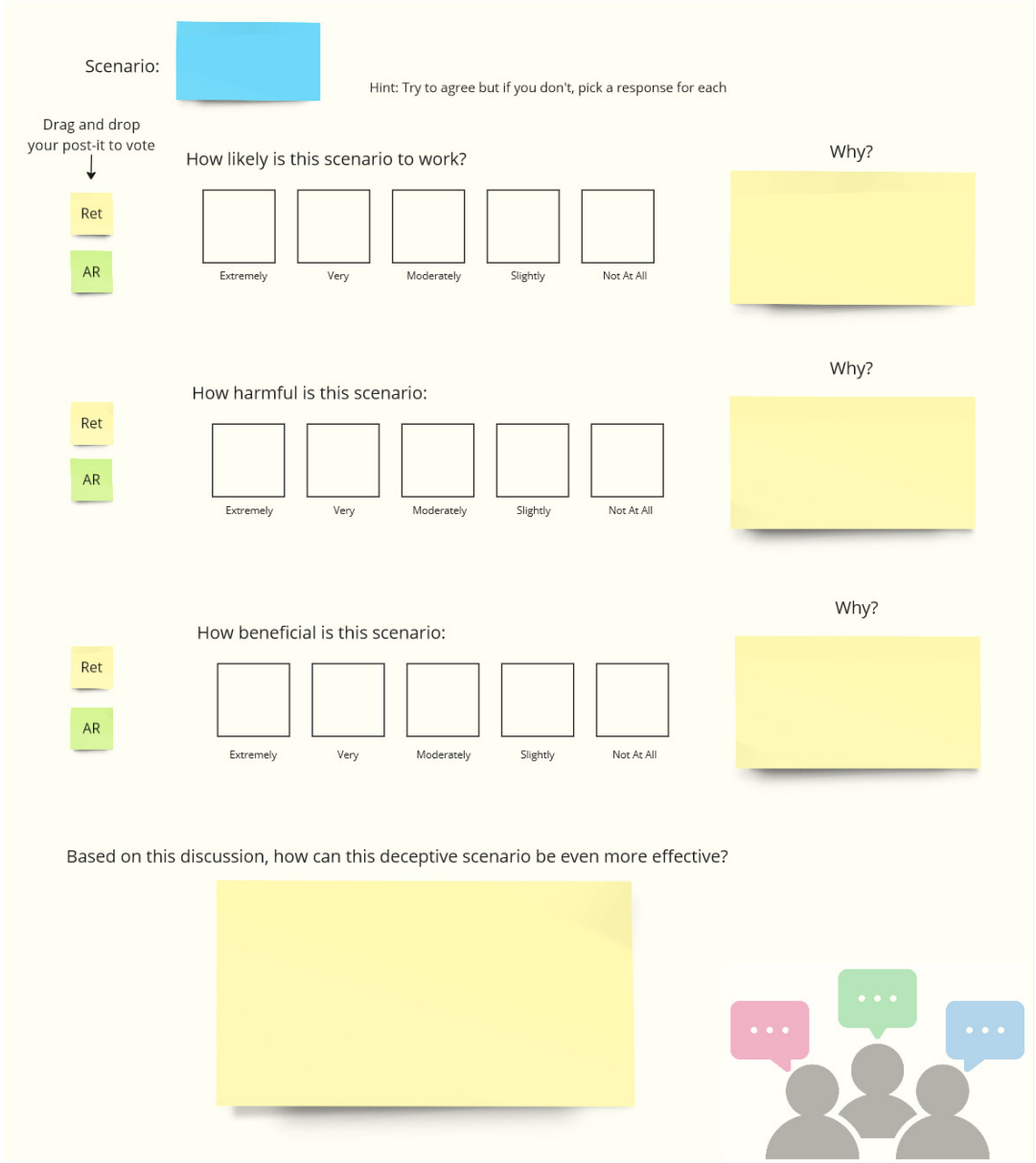

Figure 5: Discussion board