Negotiating Dyadic Interactions through the Lens of Augmented Reality Glasses

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ABSTRACT

Augmented Reality (AR) glasses separate dyadic interactions on different sides of the lens, where the person wearing the glasses (primary user) sees an AR world overlaid on their partner (secondary actor). The secondary actor interacts with the primary user understanding they are seeing both physical and virtual worlds. We use grounded theory to study interaction tasks, participatory design sessions, and in-depth interviews of 10 participants and explore how AR real-time modifications affect them. We observe a power imbalance attributed to the: (1) lack of transparency of the primary user's view, (2) violation of agency over self-presentation, and (3) discreet recording capabilities of AR glasses. This information asymmetry leads to a negotiation of behaviors to reach a silently understood equilibrium. This paper addresses underlying design issues that contribute to power imbalances in dyadic interactions and offers nuanced insights into the dynamics between primary users and secondary actors.

CCS CONCEPTS

• **Human-centered computing → Participatory design**; **Mixed / augmented reality**.

KEYWORDS

Augmented Reality glasses, real-time modification, user-bystander interaction, secondary actor

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1 INTRODUCTION

"People feel that their images are extensions of their identities. What happens to their images happens to them. What touches their images, they feel. They immediately accept the reality of any image that includes their own." —Myron Krueger

The term "augmented reality" (AR) reveals the target user in its name—the *augmented* view is for the wearer or the person wearing the device. As follows, AR research has often focused on enhancing the experience and capabilities of the wearer [29, 34, 47, 52, 53, 57, 75]. However, augmentations such as face filters affect not only the wearer, but also the person whose images appear on the target user's screen. As Kreuger observes in an early artificial reality system called VIDEOPLACE (1974), people have a sense of ownership of their images and even their virtual augmentations [31]. Thus, interaction with AR glasses is not limited only to the target user, but also involves parties who do not actively use AR glasses, often known in pre-existing literature as the non-users or bystanders [50, 72]. Yet the impact of virtual augmentations on the *the augmented*, let alone interactions between the augmented and the wearer, is still under-explored.

AR glasses, by design, create an unbalanced power dynamic between non-users and users and place non-users at a relative disadvantage. Previous commercial releases of AR glasses have had limited success because they focused primarily on augmenting the abilities of the user and not enough on how these augmented capabilities affect the social experience, privacy, and safety of non-users. The non-endearing moniker, "Glasshole", describes the point of view of a bystander observing unsocial behavior by a wearer of Google Glass, an early AR glasses product [13]. The unfavorable reception is attributed in part to the inherent design of AR glasses. A user can unilaterally introduce bystanders into mixed reality interactions without their consent by casting virtual augmentations over them [10].

In response, the HCI community has started to investigate the social implications of AR glasses and virtual reality headsets. Denning et al. investigates how the presence of AR devices affected bystanders and their privacy [10]. O'Hagan et al.'s survey study investigates bystander concerns and awareness regarding privacy infringements caused by AR glasses [49]. In a separate survey study, O'Hagan et al. characterizes user-bystander interactions, such as bystander abuse, and details concerns regarding safety, power imbalances, and ethics with virtual reality headsets [50]. Von et al. suggest the use of augmented virtuality to seamlessly integrate passerbys, or the non-users, who often interfere with the virtual reality experience of the users [67]. Conversely, Tseng et al. demonstrate scenarios in which virtual reality can manipulate the wearer to produce negative interactions with the bystander [65].

However, for AR glasses to become a socially accepted piece of technology, the AR glasses community must first change the fundamental way we think about non-wearers. Non-users are often considered as powerless individuals who are merely in the range of AR sensors and have no ability to participate or interact with the wearer and the imposed augmented reality. The current nomenclature describes non-users also as "the observer" [57], the "non-wearer" [40], "the receiver" [57], and "bystanders" [10, 49]. These terminologies, by definition, reflect the inherent disregard of non-users as stakeholders of a mixed reality space. Even if non-users interrupt and disrupt the user's mixed reality experience, as Von et al. and O'Hagan et al. mention [50, 67], they are only considered as "passerbys", or temporary visitors to a mixed reality world. Yet, if "non-users" are affected by the augmentations of the wearer and can interfere, or in other words, interact, with the mixed reality experience of the wearer, should they not be considered as active participants and even further as *co-creators* of the mixed reality experience?

In this paper, we propose a new term called **secondary actors**, which defines the subset of bystanders who are *active* participants in the augmented reality space and have some agency, or power, to negotiate their interaction with the wearers. Because we cannot identify an appropriate term from existing literature, we adopt the term "secondary actor" from film studies [61]. Secondary actors infer and interact with the primary user directly. Secondary actors are not only affected by the mixed reality experience but also collaborators who can actively co-create the mixed reality experience. Through this lens, the paper aims to answer the following questions:

RQ1: What factors contribute to the unbalanced power dynamic between the user and the secondary actor?

RQ2: Do pre-existing power dynamics between users and secondary actors change or remain unbalanced?

To answer these questions, we consider a pair of wireless AR glasses called "Spectacles" [64], a minimalist form factor of an AR device, which have iterated towards the appearance of fashionable glasses. The AR glasses in our exploration is a limited release prototype designed to expand the user's view with lenses showing virtual 3D objects overlaid on the physical world, and possesses cameras to allow for additional virtual input and manipulations for the wearer. The user of the Spectacles is not only capable of overlaying virtual layers on the physical landscape, but also on the people who they are interacting with. Unlike Von et al. [67], which describes the problems of a bystander physically encroaching into a virtual world without a VR headset wearer seeing them, the scenario in this paper is about a virtual world encroaching on a physical world without the secondary actor's seeing it.

To immerse in this scenario, we conduct an exploratory study with 10 participants in which a wearer imposes a minimalist visual augmentation in the form of a face filter on the secondary actor. To observe implicit biases and encourage participants to actively critique their interaction with the glasses, the 5 pairs of users and secondary actor participants undergo a participatory design task in which they co-design AR glasses on the whiteboard for users and non-users. Semi-structured interviews are conducted to understand the nuanced limitations and effects of AR glasses on the users and the secondary actors.

This paper has three major contributions. First, we propose "secondary actors" as a novel perspective to consider when designing mixed reality interactions with AR glasses. Next, we find the following three design factors that contribute to the unbalanced power dynamic between users and secondary actors: (1) the lack of transparency of the primary user's view, (2) the secondary actor's loss of agency over self-presentation and (3) the discreet recording capabilities in AR glasses. Finally, this paper expands previous characterizations of user-bystander interaction [50] by introducing *readjusting* and *passive and active ignoring*. We find the wearing of AR glasses leads to the negotiation of both physical and virtual spaces by the individuals involved, even in situations where the secondary actor cannot see the virtual view of the primary user. Both are ways in which secondary actors negotiate imbalances in power with the wearers. The former is a more physical reclamation of power by the secondary actor while the latter a subtle, mental negotiation that effectively maintains power dynamics between secondary actors and users. To conclude, our exploratory study contributes nuanced insights into the power dynamics between primary users and secondary actors, with a focus on addressing underlying design issues that contribute to power imbalances in dyadic interactions.

2 RELATED WORK

2.1 Everyday Use of Augmented Reality Glasses

Augmented Reality (AR) glasses are a lightweight format for accessing the augmented reality world, aimed to eventually be suitable for everyday use. Like many head-worn devices, they have evolved beyond simply being a "display[s] of an otherwise real environment augmented by means of virtual objects" as originally described by Milgram and Kishino [44]. AR glasses blend both the virtual and real world and enable "both real and virtual content across different senses" [62]. The combination is a wider range of opportunities for users to engage in otherworldly interactions and seamless transitions between the two worlds.

Several constraints prevent the adoption of AR glasses from becoming more ubiquitous. Many are technical and thus require engineering solutions, but some are social and ethical concerns, and the two types of constraints are often intertwined. AR glasses displays need to be transparent in order for the user to be able to see the physical world. Because the virtual objects in view are displayed using light, the AR glasses have to either emit a lot of light or reduce the amount of incoming light in order to compete with lighting conditions from the outside world [39]. One solution, such as in the HoloLens, Magic Leap, and Spectacles, is to use darker lenses to be able to filter more light from the view of the user so that the AR objects can be more visible. The resulting frequent use of dark lenses in the design of AR glasses obscures the primary user's face in a similar fashion to regular sunglasses; as a social side effect, this affects the ability of secondary actors to perceive the primary user's emotions [66] and inhibits communication between the two people.

A similarly large technical limitation is the narrow field of view within today's AR glasses, resulting in a visible border between the areas that the user can see augmented and the areas of their vision that cannot be augmented [21]. This results in an inability to visualize full objects that are close to the user, which in turn results in requiring secondary actors to be a minimum distance away if the primary user wishes to view them fully augmented.

The cost and limited release of most consumer-oriented AR glasses [42, 64, 71] likely result in a long period of time when primary users enter situations with secondary actors who are not wearing AR glasses. Previous work shows that this lack of access to AR glasses results in a power imbalance that may cause ethical issues such as: the primary user having access to information that the secondary actor will not, the primary user being able to deceive the secondary actor about what is being displayed, the ability for the primary user to augment secondary actors even in a demeaning or bullying attitude [70], or the primary user acting on information that may be deceiving them or their perception in a way that may harm the secondary actor [65].

2.1.1 Audience and Ergonomics of the Device. Prior works investigate the effect of using smart glasses during face-to-face interactions. One common issue identified is the distracting nature of the hardware, which is often heavy and uncomfortable, hindering the wearer's performance and attention [40, 59].

Of the AR devices on the market, many have pivoted towards enterprise usage as opposed to targeting the consumer market. HoloLens glasses are sold in special formats for industrial use and construction use [42], Magic Leap refers to its Magic Leap 2 glasses "the most immersive enterprise AR device" [38], and Google calling its latest glasses offering the Glass Enterprise Edition [37]. One of the large outliers in this enterprise focus is the Snap Spectacles [64] that have a purely consumer focus, although they are only currently available to developers. Due to this consumer focus, the Spectacles look the most similar to a pair of regular sunglasses as that form factor is closer to consumer expectations.

This consumer-based focus pushes AR glasses closer to being indistinguishable from a pair of sunglasses at a glance, as the next generation of mass-consumed personal computing requires wearable devices to become not only utilitarian but also fashionable. Unlike AR on smartphones, which forces users to at least hold and direct the phone to others, AR glasses can be relatively unnoticed by others. Similar to spy glasses [4, 69], this results in AR glasses having the capability to record and unilaterally digitally modify the world around them without being noticed by others. This is a concern for consumers, as evidenced by the failure of the original Google Glass due to concerns around privacy [32]. These concerns are echoed on the release of the first Snap Spectacles that allow users to simply press a button to record a 10 second clip that would be streamed to the user's Snap account [35].

As a result, the trend towards a minimal form factor for AR glasses raises similar ethical issues regarding consent, deception, and agency for both the user of AR glasses and the secondary actors [23, 30]. The communication barriers and ethical concerns that result from limitations surrounding AR technology are reasons why this work is about consumer-oriented everyday use, with specific focus about the negotiation and power dynamics between users and the secondary actors.

2.2 Wearer-Bystander Interactions

Research on social AR interactions has centered on understanding the effects of visual enhancements for primary users [47]. Rzayev et al. and Lazaro et al. investigate how push notifications and added textual information affect primary users' experiences and social interactions [34, 57]. McAtamney and Parker find that behaviors induced by AR glasses, such as AR glasses distracting the user's attention, are not always apparent to the non-wearers [40]. Similarly, Rzayev et al. find that augmenting primary users' vision with digital notifications during social interaction does not entirely interrupt the conversation [57].

Recent studies examine social interactions between users and bystanders. Miller et al. studies how augmented logos that block participants' faces affect user and non-user communication [45]. Rixen et al. compare wearer and non-wearer perception of visual alterations by showing screenshots in alternate points of view in a between-subjects survey study [55]. O'Hagan et al. conducts extensive surveys to investigate and characterize user-bystander interactions for both VR headsets [50] and AR Glasses [49]. Similarly, Tseng et al.'s work [65] conceptualizes potentially harmful scenarios with experts in the field. However, surveys and interviews cannot capture the subtle changes in behaviors observable only in lab settings and elicit responses about attitudes toward proposed scenarios. There is a visceral difference between *experiencing* an interaction with AR glasses staring at you, compared to being asked to recall or imagine an experience. Thus, our study directly observes participants and their interactions.

Denning et al.'s work involves participants directly in AR scenarios by conducting a wizard-of-Oz evaluation in which they interview and record the reactions of bystanders in the presence of a user with a mockup AR glass in a public cafe [10]. While they are able to detail bystander interactions, the setup of the study limits their ability to understand user-bystander dynamics and the dynamics of dyadic interactions. This study extends previous paradigms by offering hands-on experiences to the participants. In addition, by including a range of selections of filters for the primary users, the current study simulates a real-life social scenario and fosters more natural behaviors for the participants.

While many AR studies focus on the design experiences and psychological effects for primary users, how the technology affects the interpersonal power dynamics between primary users and secondary actors is still under-explored. In particular, when filters are used in AR glasses, the primary audience is the other person rather than the AR users. This shift in focus highlights the need to examine the effects of AR glasses on secondary actors. Therefore, the current paper aims to fill the gap in the literature by incorporating the perspectives and experiences of these stakeholders, thereby providing a more comprehensive understanding of the effects of AR glasses during social interactions.

2.3 Embodiment within the Virtual World

The virtual world offers the opportunity to be embodied in both unrealistic and realistic ways. Yee and Bailenson found that the avatars that users embody in VR impact their behavior [73]. Users with taller avatars negotiate more aggressively than users with smaller avatars, but they do not notice a difference in the way they are perceiving the

Study Activity	Duration	Participants Co-located	Recording	Study Objective
1. Survey	15 Minutes	Yes	N/A	Collect participant's demographic info, prior AR experience, and interpersonal closeness with paired participant
2. Interaction Task	15 Minutes	Yes	Video Audio	Provide participants with first-hand user and secondary actor interaction experience as they complete a modified desert survival task
3. Participatory Design Task	10 Minutes	Yes	Video Audio	Encourage participants to think and articulate limitations of the AR glasses and facial augmentation and co-design features for users and secondary actors via a whiteboard session
4. Semi-Structured Interview	45 Minutes	No	Audio	Understand participant's knowledge of AR, record interaction task limitations, detail self-reported effects of AR glasses and facial augmentation, provide different scenarios to understand contextual effects

Table 1: Summarizes study activities and objective of each activity. Study activities are conducted in sequential order as listed. Paired participants are present in the room for study activities 1-3. The survey activity requires paired participants to be co-located, or present in the same room, to answer interpersonal closeness. The semi-structured interviews are conducted individually for each participant in parallel in different rooms.

world. Yet, with AR glasses, the difference in digital representations between the primary and secondary actors may be unidirectional and could be under the complete guidance of the primary user.

Because users select personal AR filters for themselves on social media and video conferencing systems based on goals they want to achieve with the filters [20, 43, 54], the primary user may similarly use AR filters on secondary actors that they see in pursuit of their own goals. A similar dynamic can be found in streaming culture, where the viewers apply filters to the streamers. Streamers use filters as an incentive to attract and encourage more engagement from the viewers [36].

Wolf and Grodzinsky recognize the ability for the primary user to augment the visual appearance of others within camera range, even in a demeaning or bullying attitude [70]. Primary users also report feeling less connected to secondary actors compared to cases where augmented reality was not used [45], which could affect the way they treat the people around them. Depending on the configuration of the augmented reality system, the people being viewed often lack the agency over their own appearance, as it's up to the primary user to control the visual settings. However, the secondary actor sometimes has an opportunity to negotiate with the primary user in their interaction.

Modifications can also be realistic, especially with further advancements in technology that support this goal. Technology for altering people's visual appearance such as Deepfakes also have interpersonal consequences [19]. Similarly, AR glasses enable an individual to make visual alterations of others without advanced technical effort via the use of filters. Deepfakes may expand the range of modifications that can be done to the secondary actor, challenging humans' perceptions and what people can trust, just as filters in AR glasses also challenge secondary actors' agency over self-expression. The unilateral visual alterations from AR glasses questions secondary actors' intended self-presentation, and the possibilities of what alterations are possible may be increasing rapidly.

Overall, the technical and social constraints of AR glasses are interrelated when considering their adoption for everyday use. There has been work covering the interactions between the wearer of AR devices and secondary actors, but a fundamental question remains about how secondary actors negotiate their position in the virtual world. However, it's important to take a step back and assess whether we are taking a *reformist* stance by proposing patches to a pre-existing design that does not work [18]. Instead, we also seek a critical approach to study the effects of the underlying design of the AR glasses themselves.

3 METHOD

We design a series of exploratory tasks to articulate participants' existing and potentially nuanced subjective experiences. The study activities are divided into four major parts, all of which are summarized in Table 1. A total of 10 participants across various physical and online spaces are recruited. As Table 2 shows, there are 5 male and 5 female participants and they mainly range between the ages of 20-24 years old (median = 23.5 years, SD= 5.83 years). Only one participant is 41 years old. Participants are recruited until theoretical saturation [8, 16] is reached. Participant behavior and interview content became redundant after three pairs. The relatively quick saturation point is unsurprising given the somewhat homogeneous demographic of the participants and is discussed further in limitations.

3.1 Study Activity #1: Survey

Before the interaction tasks, each participant is randomly paired with another participant and asked to complete a 15-minute survey. Each participant is linked with an ID that indicates the type of role (P = Primary User, S = Secondary Actor) and their interaction pair number. The survey is modeled after the technology acceptance model [41] and requires each participant to indicate their age, gender, and proficiency and confidence with AR glasses on a 7-point

ID	Role	Past AR Experiences	Social Proximity	Gender	Age
P1	Primary	Novice, experiences with AR games on headsets	Stranger	Female	23
S1	Secondary	Competent, developed on AR headset during internships	Stranger	Male	24
P2	Primary	Novice, experiences with AR games	Acquaintances	Female	23
S2	Secondary	Proficient, AR researcher	Acquaintances	Female	24
P3	Primary	No prior experiences	Stranger	Female	24
S3	Secondary	Competent, designed and developed museum AR applications	Stranger	Male	23
P4	Primary	Novice, experiences with AR games on mobile devices	Stranger	Male	20
S4	Secondary	Novice, experiences with AR games on headsets	Stranger	Male	24
P5	Primary	Novice, experiences with AR games on headsets	Stranger	Female	22
S5	Secondary	No prior experiences	Stranger	Male	41

Table 2: Summary of participants experiences with AR, social proximity with their partner, gender, and age information. The study includes a heterogeneous mix of participants across gender and experience. Half the participants identify as Male and the other Female. Seven out of ten participants are either novices or had no prior experiences with AR glasses. The study mainly reports on interactions between strangers as only one pair of participants were acquaintances. *Users* wore the AR glasses in the pair, while *Secondary* actors did not. The ID indicates the type of role (P = Primary User, S = Secondary Actor) and their interaction pair number.

Likert Scale. The results are summarized in Table 2. The coding for "Past AR Experiences" in Table 2 is elaborated in section 3.5.

Since interactions between two people can be affected by the closeness of their relationship, we co-locate the randomly paired participants so that they could see and describe their interpersonal closeness with each other. Participants individually describe their relationship with the other participant on the survey using the following scale: "family members", "close friends", "non-close friends", "acquaintances", or "I have never met this person before". This scale is adapted from the Inclusion of the Other in the Self scale, which measures interpersonal closeness [1, 15]. 8 out of 10 participants labeled their social relationship with their partner as complete strangers, while the remaining 2 participants labeled each other as "acquaintances".

3.2 Study Activity #2: Interaction Task

The study is comprised of 5 interaction sessions in a visual and audio-recorded lab setting. Each session involves two participants, and each participant is randomly designated as a primary user and secondary actor. To avoid biasing the secondary actor with information on what the primary user can see, the primary user temporarily exits the room to put on AR Glasses called "Spectacles". They are then instructed to choose among 5 benign Lens Studio face filters [63] resembling a deer, cat, bear, clown, or pig-bunny.

As seen in Figure 1, the face filter is overlaid on top of the secondary actor's face. While there are many forms of virtual augmentation, we choose to investigate the effect of face filters because facial alterations are the most visually salient during face-to-face interactions [74] and directly alter visual features of the secondary actor. To remove confounding variables, this study intentionally uses simple face filters as simple forms of appearance augmentation and does not provide the user with more complex choices. However, to simulate a more realistic scenario and encourage engagement with the AR glasses, the user is allowed to change the filter midway to a different one.

The primary user rejoins the secondary actor with the filter already activated. The participants are then instructed to complete a 15-minute modified version of the desert survival task [33] in which participants must communicate and collectively list 10 items needed to survive in the desert. The task is known to encourage interaction and communication among participants across various disciplines [27] and to be helpful in understanding people's perception of social robots [28], power dynamics in project teams [68], and parent-adolescent interactions with varying socioeconomic backgrounds [7]. The task also served as a first-hand experience of a user-actor interaction for those with no prior exposure to AR glasses.

All primary users are able to view the filters applied to the secondary actors with minimal guidance and no users report frustration with this initial setup in the semi-structured interviews. This suggests that the user experience is easy enough to understand that users can easily apply filters to more varied situations. Similarly, no users report being physically uncomfortable while wearing the AR glasses, either with the physical form factor or the technology causing nausea, which could impact the primary user's behavior.

3.3 Study Activity #3: Participatory Design Task

Next, the participants are instructed to design AR glasses for both wearers and non-wearers using the whiteboard. The purpose of the task is to encourage participants to actively think about limitations in their interaction experiences during the previous interaction task. This task is inspired by the participatory design framework in which the stakeholders of the interaction contribute to the design of a product that would affect them [3, 17, 26, 58]. The secondary actor is also provided with a chance to try the AR glasses. According to the creative sense-making framework [9], role-playing and open-ended collaborative sketching help participants to make sense of how they would engage with AR glasses, a scenario that is previously unattainable or out of the norm of their daily lives.

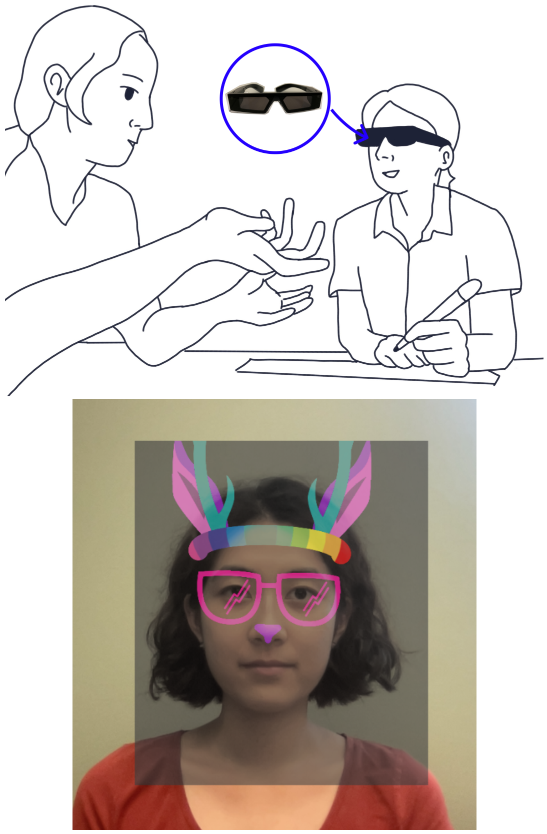


Figure 1: Example arrangement of two users interacting during the desert interaction task. The primary user is wearing AR Glasses during the interaction, while the secondary actor is not. The bottom photo demonstrates an Example of a "2D Objects" face filter that is laid over the secondary actor [63]. Dark gray area signifies 26.3 diagonal field-of-view on Spectacles 2021 [64].

3.4 Study Activity #4: Semi-Structured Interview

Two experimenters each conduct a 45-minute, semi-structured interview in separate rooms in parallel - one experimenter with the secondary actor and another with the user. Each participant is asked about their experiences in the two preceding tasks, specifically focusing on the influence of AR glasses on their interaction with the other participant. Given that both participants can freely engage with the Spectacles during the participatory design session, the secondary actors' perceptions of the AR glasses may be affected by their direct experiences. To address this potential influence, we incorporate questions during the semi-structured interview that encourage participants to reflect on how their emotions and attitudes toward the AR glasses evolve by asking their responses in sequential order of the study activities.

We also present the participants with different social scenarios to understand which contexts users find the use of AR glasses beneficial, harmful, and socially acceptable. In addition, we ask all participants to respond to these scenarios once by assuming the role of a secondary actor and another time as a user. The scenario and role-based questions are again drawn from the creative sense-making framework [9] to help participants articulate more tangible and contextually rooted insights into their experiences. The interviews are audio recorded only and manually transcribed. An overview of the tasks with research goals and duration is included in Table 1. This study is approved by our institution's IRB, protocol #2022003376, as part of expedited review.

3.5 Coding Past AR Experiences

The past AR experiences of participants are coded after completing all study activities, primarily utilizing the results from the semi-structured interviews. While the survey asks for self-reported familiarity and confidence with AR and AR glasses, it does not explicitly ask participants to rate their proficiency with AR glasses. Thus, we code their proficiency based on the semi-structured interviews in which participants elaborate on their past experiences with AR and AR glasses. As summarized in Table 2, out of the 10 participants, 2 of them have no prior experiences, 5 participants are novices, 2 are considered as competent, and 1 as proficient. Note that the 3 participants who are coded as "competent" or "proficient" are all designated as secondary users. This is an artifact of the random assignment at the beginning of the experiment, a point at which the participants' proficiency level was unknown – further discussion is included in the limitations section.

Based on Dreyfus's five-stage model of adult skill acquisition [12], participants are labeled according to the following four categories: "no prior experiences", "novice", "competent", "proficient", and "expert". As the name implies, people with no prior experiences with AR technology are labeled as "no prior experiences". Novices are participants who had limited experience with AR technology and required assistance during the interaction. Competent participants are those who have used AR technology before and do not need additional support to complete the task. Proficient participants can confidently and independently interact with AR technology and have the ability to diagnose issues confidently. Finally, experts are participants who can identify and implement a roadmap for future AR technology development.

3.6 Analysis of Study Activities

The analysis is guided by Glaserian Grounded Theory which stipulates theories to emerge from the data [8, 14, 16]. This study considers the survey reports, the drawings from the participatory design task, and all audio and video recordings as data sources. Following Grounded Theory, we start with open coding, or the process of breaking our multimodal data down into chunks to find initial categories [16]. First, we create descriptive notes with participants' quotes from the transcripts of the interviews and participatory design task such as "glasses looked like 3D movie glasses", "drew blinking lights feature", and "participant adjusted for user". The coding also identifies whether the participant is a "user" or a "secondary actor". To capture the emotional effects to the AR glasses, we adopt Denning et al.'s coding of bystander sentiments on AR recordings [10], and code user and secondary actors' sentiments during the interaction task as positive, negative, or indifferent.

While Glaserian Grounded Theory commonly uses interviews as the primary source of data, this study also open codes behavioral changes from video recordings of the interaction task. According to the conversational analysis approach [24, 48], to fully understand an interaction, one must consider sequential context, or the order in which actions unfold. This often requires analysis of body language and turn-taking in addition to the analysis of the conversation. Thus, physical changes such as body language, turn-taking, posture, and location were coded [22, 24, 25, 51]. We also note sequential context by linking parts of the transcript to relevant moments in the video recordings.

Next, we use axial coding to find abstractions that explain connections between codes via an iterative process. We first group the codes into 7 initial categories: hardware limitations, visual alterations and reputation, trust and situational context, reactions to AR filters, shifts in body language, reduced communication cues from AR glasses, and recording on smartphone versus AR glasses. Next, we find connections between the categories and sub-categorize each of the categories by primary users and secondary actors to compare and contrast reactions between the two parties. In the process, two major themes emerge: (1) factors that cause disparate reactions to AR glasses and face filters between users and secondary actors and (2) the physical and mental ways participants adapt to the presence of AR glasses.

Keeping these two themes into consideration, we start the selective coding process, or the development of a single explanatory theory that explains the themes and observations in the data. We revisit the original open codes and categories to re-examine and answer why we observed the two themes that emerged from the data. We find that power imbalances between users and secondary actors induced by the design of AR glasses and face filters explain both themes. Wearers react much more positively to the interaction task than secondary actors because the glasses are designed in favor of the wearers. Furthermore, participants adjust physically and mentally as a way of negotiating with the pre-existing power dynamics.

4 PARTICIPANT DISCOMFORT WITH IMBALANCES OF POWER

Based on the surveys, interaction task, and design exercise, we identify three distinct factors that induce the imbalance in power between secondary actors and AR users: (1) the lack of transparency of the primary user's view, (2) the loss of agency over self-presentation and (3) discreet recordings. Additionally, we highlight how context and situational dependency affect participants' acceptance and comfort level with AR glasses.

4.1 Lack of Transparency of the User's View

Power tilts in favor of primary users because AR glasses are designed to lack transparency in face-to-face interactions. This imbalance manifests in the form of contrasting sentiments between primary users and secondary actors during the desert survival task. Despite minor annoyances, users feel positive towards the experience because they are empowered by AR glasses. They gain the ability to feel more relaxed in conversations. While primary users' views are affected by the lack of physical transparency, their abilities are not strictly diminished. Instead, they exchange certain innate capabilities such as the ability to see clearly for the augmented ability to feel more relaxed in conversations. On the other hand, secondary actors feel unease because they are disempowered. They are placed at a relatively compromising state such that they are unaware of what the user is seeing and their usual ability to understand social cues diminishes because of the physical opaqueness of the AR glasses.

4.1.1 *User Sentiments During the Desert Survival Task.*

Face filters on AR glasses positively affected AR users by easing their nervousness. During the interviews, we ask AR users to describe how the AR glasses affected their interaction and if anything made them uncomfortable. Most AR users [P1, P2, P4, P5] feel more relaxed when interacting with the other participant because of the "cute filters". P4 states that the filters "made the conversation a little more humorous". P2 comments how "there's a filter on her face so I think she's more easy to talk with, more friendly". Similarly, P5 mentions that the filters made it easier to talk to their partner, because the filters reduced her usual nervousness when talking with a stranger. Thus, while the face filter is a simple virtual augmentation applied for a short amount of time, it empowers users with the ability to facilitate conversations by reducing social anxiety when talking to strangers.

We also find that users are willing to trade off their own abilities in exchange for augmented capabilities, but they do not experience complete disempowerment. Primary users' views are affected by the dark shaded area seen in Figure 1, a common hardware feature to project virtual objects onto the glasses with good contrast from the physical background [39]. While users find the dark shaded area on the glasses [P2] and the instability of the face filter at different angles [P1, P2, P5] to be annoying, the inconveniences do not affect the overall quality of the conversation. While P2 is the harshest critic of the dark shades because they prevent her from seeing the other person, she describes the overall experience with the glasses in a positive light because she benefits from the face filter's ability to reduce nervousness in conversation. Thus, while there is a trade-off in abilities, there is not a complete disempowerment in P2's abilities to communicate. In addition, many of the users find the face filter unstable and needed a "specific angle to catch the faces" [P2]. From the video analysis, we see that this may have caused more rigid body posture for the three primary users as they had to be more still to stabilize the filters. However, all three users [P1, P2, P5] who express inconvenience with the instability in face filters are also the same users who feel empowered by them. Thus, while users compromise fluidity in movement, they gain the ability to talk more comfortably.

4.1.2 *Secondary Actors Sentiments During the Desert Survival Task.*

On the other hand, no secondary actors express positive sentiments during their interaction with the AR glasses. Four of five secondary actors [S1, S2, S3, S5] express slight unease in the presence of AR glasses and only one of the five secondary actors [S4] feels indifferent.

Participants report they feel slight unease because they "don't know what's happening from the other side" [S1, S2, S3]. S3 elaborates that only "the person who is wearing the glasses can receive multiple information, ... but for the other person it's just talk." By comparing himself with the user, S3 expresses he is at a relative disadvantage because he can only use 'talk' or his innate verbal abilities to interact with the user while the user has augmented capabilities in addition to their innate capabilities. In fact, S1 even "feel[s] the other guy is more superior than me because he can see something I cannot see anymore." S1 feels relatively inferior because the glasses are innately designed to empower the user with more information than the secondary actors.

In addition, the dark shade of the AR glasses disempowers secondary actors because it reduces their ability to gain social cues from the user. While we observe similar effects for users, secondary actors do not have the same opportunity to compensate their diminished capabilities with augmented capabilities like users do. S3 states the dark shades prevented them from receiving social cues from the user's eye contact. As a result, S3 didn't "know whether [the user could] correctly receive [their] ideas". S3 loses the ability to know whether the user understands what he is saying. S2 mentions how she "couldn't tell [the user's] expression ... I could tell from her voice but like I think in social interactions your gaze is very important and I couldn't see that". Similar to S3, S2's ability to understand expressions diminishes because the shades block her from retrieving social cue information from the user's eye gaze. These phenomena draw a striking resemblance to Viola et al.'s finding that sunglasses act as a "social shield" to mask people's emotions and expressions [66]. *Thus the virtual augmentations and physical design of AR glasses only serve to widen the gap of power between user and secondary actors.*

4.2 Violation of Agency over Self-Presentation

Users are innately more powerful than secondary actors because they have the ability to change the appearances of secondary actors, while secondary actors cannot. This is problematic because individuals value agency, or control over how others view them. Self-image is highly linked with an individual's self-identity, so the way someone presents themselves is critical, particularly to one's self-esteem and power over oneself [2].

"What's she doing with the glasses? Is she changing my appearance in any way? That would kind of make me worried" [S2]. It only takes the user a couple of taps on the side of the glasses to make the secondary actors feel uncomfortable. Even though this is a controlled lab study, and S2 doesn't "believe the intentions of the study were nefarious" and feels like she is in a "safe environment", S2 is still concerned about how her physical appearance is being affected. Her self-agency over her self-presentation is compromised because she doesn't know what's happening to her physical appearance.

Many participants express heightened unease in scenarios where AR glasses breach their agency or power of self-presentation as secondary actors. Both S2 and S4 mention that they would be uncomfortable if a filter forcefully imposes nudity onto them because the filter "portrays [them] in a negative way... distorts [them] in a way that [they] would be uncomfortable with". Nefarious filters not only compromise a user's physical appearance and image, but also diminish users' agency over their physical presentation. P4 draws parallels to Deepfakes and remarks that if AR glasses enable others to assume another person's identity, AR glasses would be harmful because they could "ruin their image". P4 feels discomfort because AR glasses could help misrepresent a user, completely distort an individual, and result in total loss of control over one's self-image.

In addition, we find that the agency over self-presentation can also be violated by recording capabilities on AR glasses. *"A bird pooped on me. Now I feel terrible. My appearance isn't great I don't want to be recorded or filtered in any sort of way. It would depend on my feeling for my appearance, for that moment."* S2 does not want recordings nor AR interactions because she feels self-conscious of the way she looks. While she has the ability to control her appearance for the moment, or for more ephemeral interactions, recording makes the interaction and her compromised appearance permanent. Thus, once the recording of her unflattering image becomes disseminated to the public, she loses total control over her self-presentation because she would not be able to stop the spread of the video. While the scenario of bird excrement may seem trivial, the potential misuse of inappropriate filters, such as those of a pornographic nature, combined with recordings, raises serious concerns. Such misuse could not only undermine individuals' control over their self-presentation but also violate their personal boundaries and dignity.

4.3 Discreet Recording

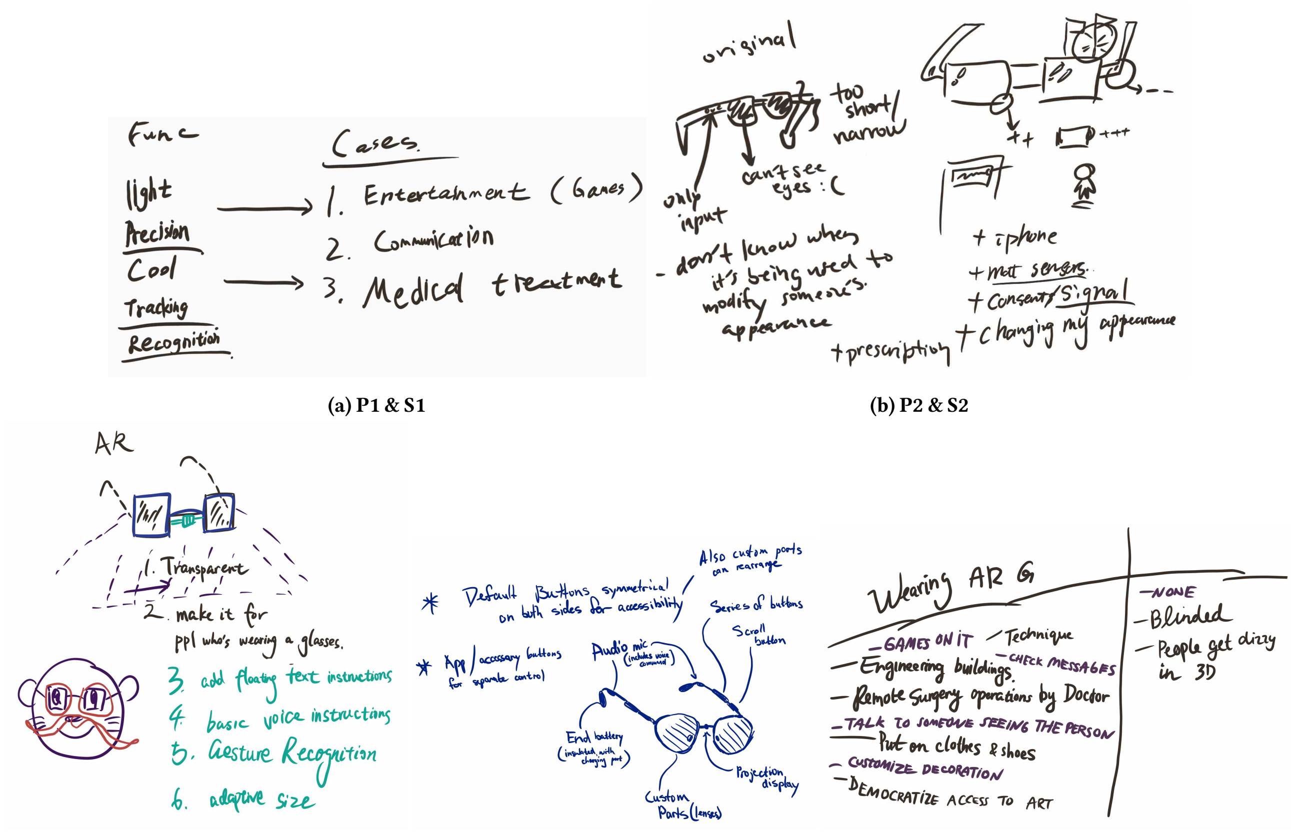
As demonstrated by the bird poop scenario, recording capabilities in AR glasses amplify the power imbalance in favor of the primary users. Yet, given that secondary actors also have access to phones, the mere capability to record does not fully explain why participants think they will feel discomfort as a AR user.

The ability to record *discreetly* is what makes participants feel uncomfortable about AR glasses. The subtle form factor and ease of recording [10] facilitate discreet recording. Mid-way through our interview, we ask participants if they were aware that Spectacles could record videos. Participants were verbally or physically startled to be informed that the AR glasses had the capability to record [S1, P1, P2, S2, P3, S3, P4, S5, P5]. They did not notice that it was possible to record with the AR glasses. They dislike the fact that AR glasses have the capability to record because, as described by S2, "There's less barrier to [record]". A simple button click is required to record on AR glasses. This discreet attribute is unnerving [S1, S2, P4, S5] and to participant S5, "That changes everything" because people can record without their knowledge. Participants point out that AR glasses are not like phones because phones need people to recognizably point at the other person with their hand protruding out to record [S2, P4, S4, S5]. AR glasses make it easier to record without the awareness of the secondary actor. The fact that there are no mechanisms to detect AR glasses unless one looks at it closely or avoids people with glasses completely signifies that there is no easy way to avoid the application of filters. In other words, AR users have more power than secondary actors because they have the ability to record more discreetly.

Effectively, the lack of awareness in recording affects the secondary actors' ability to willfully consent. Participants feel like unawareness of recording is unsettling because that leaves them with no choice. P5 states that people who have AR glasses "have a choice, [but] people who do not wear the glasses... do not have a choice... to be recorded or not". Secondary actors' rights to privacy are taken away [S3, S5] unknowingly. More importantly, without prior knowledge that a recording is taking place, secondary actors are stripped of their right to choose to participate in a recorded action. There is an absence of voluntary participation.

4.4 Conditioned by Situational Context Who, What, Where, When, How, and Why

Similar to Denning et al.'s findings of AR recordings [10], we find the use of AR glasses are impacted by context. Certain situations



(a) P1 & S1 **(b) P2 & S2**

(c) P3 & S3 **(d) P4 & S4** **(e) P5 & S5**

Figure 2: Results of the participatory design task. P2 & S2 and P3 & S3 are the only two teams that add features for secondary actors. From the drawings and the tasks, we are able to corroborate concerns users had with AR glasses and implicitly understand participants’ biases in the design of AR glasses. Figures have been redrawn for legibility.

have clearer intentions and are more transparent to individuals. Particularly, in a public setting such as a classroom or business meeting, many participants feel comfortable with the presence of AR glasses because there is a level of trust that people will behave or act appropriately [P4, S5, P5]. Participants also point out that they do not feel significant discomfort or unease during the study because they are under the assurance that they were in a safe space [S2, P4, S4, S5].

However, multiple participants express discomfort interacting with primary users who are strangers because the intentions of the stranger are unclear [S1, S2, P4, S5]. Participant S5 explains that they may “turn [their] face to the other side” because they do not know what the stranger is doing. There is a lack of transparency in intention, so secondary actors cannot trust the primary user with the power to control their appearance. On the other hand, “as long as they have good intent” many participants state they “don’t object to being filtered” [P1, S2, S3, S4, S5, P5]. Thus, all participants do not mind if they are interacting with someone they are close with such as a friend or a family member, because they trust them. As S2 states, “*the proximity I feel with them correlates with how much freedom they have with the filters*.” Thus, situational context influences people’s perception of transparency of intention and who they feel comfortable with having the power to change their appearance.

5 INSIGHTS FROM PARTICIPATORY DESIGN

5.1 Evidence for Lack of Transparency and Violation of Agency over Self-presentation

We find concerns regarding transparency and violation of agency over self-presentation also appear in the participatory design task. From the conversations in the participatory design task and the drawings of the designs, we are able to tell what the participants found uncomfortable during the interaction task. Note that concerns regarding discreet recording are not mentioned because at this point in time all participants are unaware of the recording capability in the AR glasses. The participants find out about recording capabilities only in the interview process. The drawings and results of the participatory design task are summarized in Figure 2.

Participants frequently modify the physical features of glasses to increase transparency. Two teams [P2, S2, P3, S3] express the need of more transparency in AR glasses for eye contact. S2 wants to “change it so I can see [P2’s] eyes” and even writes on the board “can’t see eyes”. P2 also comments that the glasses “are too dark”. This is referring to the dark shaded area as seen in 1 which is often seen in AR glasses to project virtual objects onto the glasses. S3 expresses to P3 that they "cannot see whether you're looking at me" and wants more transparency in the lenses. Thus, in their drawing, P3 and S3 add light blue shading to indicate transparency in the glasses.

We also find participants designing features that simultaneously address concerns of transparency and agency over self-presentation. P2 and S2 design "a button, or light" indicator that changes colors depending on the type of augmentation the AR user sees. Similarly, P4 and S4 add a projecting functionality in which primary users can project holographs of what they're seeing. These features address the concern on transparency in communication by indicating to the secondary actors that AR glasses are being used and shed some information on the content the AR user sees. The changing lights and holograph themselves also address the issue over self-presentation because they empower secondary actors with more knowledge of the types of virtual alterations being made.

5.2 Implicit Participant Biases in AR Design

Figure 2 documents the sketches produced by the five pairs of participants during the design sessions. A noteworthy observation is that most of the features were designed for AR users, despite being asked to design glasses for both users and non-users. Throughout the five design sessions, participants only propose two features to help non-users: the indicator light to inform the non-users about the functionality of AR glasses and the holographic projections to share the augmented graphics with non-users[P2, S2, P4, S4].

S1 and P1 list three scenarios – entertainment, communication and medical treatment – in which AR glasses could be helpful for primary users. P4 and S4, as depicted in their AR glasses drawing in Figure 2, incorporate various features, from audio microphones to enhance voice commands to custom lenses, in order to improve the communication and style of AR glasses for users. P3 and S3 primarily discuss "how to put touch bars on the glasses" and "adjusted [face] recognition" for more seamless communication.

Interestingly, even P2 and S2, the only team that designed primarily for non-wearers, discuss various input methods such as voice control and a wider field-of-view to enhance the experience of primary users. Similar to S1 and P1, S5 and P5 list multiple use-case scenarios for AR glasses wearers in areas such as gaming, healthcare, and architecture. In the follow-up interview, S5 describes the experience as "confusing", admitting that they [S5, P5] find it challenging to think of features for non-users, leading them to concentrate on features tailored for AR glasses wearers. While we cannot make broader claims given the scope of the study, we think this may indicate that there may be an implicit bias in the current mental model of people that makes them think AR glasses are for the wearers and not for the secondary actors.

6 NEGOTIATIONS TO AN IMBALANCE OF POWER

Given the imbalance in power, the next question we asked is *how do participants react to it? Do they accept the new power dynamic? If so, in what ways?* We observe that some participants exhibit interrupting [50] in which they ask users about what they are seeing [S1, S2, S4]. In a way, this is an act of secondary actors to regain some control over the situation by knowing what filters are being used. We also find two subtler ways in which users react to the imbalance of power: readjusting and ignoring. The former is a delicate dance in which wearers and secondary actors physically negotiate to change the power dynamics. The latter is a subtler negotiation in the minds of the participants that effectively maintains power dynamics.

6.1 Readjusting

Physical changes in the interaction shift the default user-actor power dynamic. Participants in the desert survival task have a default power imbalance in favor of the user because of the AR glasses. However, in S1 and P1's session, we observe shifts in this default power dynamic.

During the first few minutes of the session, P1 readjusts her face to different angles while talking to S1 to overlay the face filter on S1. P1 is unilaterally enforcing her augmented ability onto S1. Given this noticeable movement, P1 asks what S1 is seeing. S1 verbally disrupts the dynamic and tries to regain knowledge of the unknown. P1 expresses that she sees some face filters and that if she "turn[s her] face a little bit to the other side then there will be no filter". S1 has regained some power over the situation with this knowledge.

From this point on, S1 no longer passively relies on P1 to gain knowledge, he instead actively takes control. He readjusts his body posture. He sits significantly more upright, physically leans closer to the AR user, and rotates his face towards the primary user more frequently. These changes in behavior are corroborated by S1 during the interview.

The observed phenomenon is not fully explained by O'Hagan et al.'s three user-actor interaction types: demoing, interrupting, and co-existing [50]. While the user and secondary actors are co-existing in that they share the same physical space, S1 and P1 are not directly interacting with each other. S1 is interacting with his virtual self to help P1 have a better virtual experience. In other words, S1 isn't interacting with P1's physical embodiment, but his own virtual embodiment. He has learned to perform in the virtual space as an active participant. As a result, he shifts the power dynamic in his favor because he gains the ability to directly control his virtual augmentation.

In addition, while O'Hagan et al.'s definition for co-existing only includes the secondary actors reacting to the VR user, in this case we also observe P1, the AR user initially reacting to S1's face for better filter alignment. Thus, we extend O'Hagan et al.'s user-actor interaction categories with a new interaction type called **readjusting**. Readjusting is a subtle behavior where the two users readjust their postures, in a way negotiating how the secondary actor is perceived by the user, through shifting bodies so that the angle and distance to the AR glasses is acceptable to both users. It is a *collective* change in that both users are physically shifting for a common goal, the betterment of the AR experience.

6.2 Passive and Active Ignoring

In the presence of AR glasses, users and secondary actors both perform in the physical space and the virtual space. However, during a user-actor interaction, not all secondary actors are like S1 and are conscious of their ability to manipulate the virtual space. On a similar line, not all users are conscious of their ability to choose inaction to refrain from affecting the secondary actors who believe they can perform only in the physical space. These are special types of interactions in which negotiations serve only to *maintain* the unbalanced power dynamic that is by default in favor of the user.

We call such negotiations *ignoring* and they describe shifts in cognitive states of users and secondary actors as a way to cope with the imbalances in power. We define two types of ignoring: *active ignoring* and *passive ignoring*. Active ignoring is when the participants are aware of the effects of the AR modality and consciously suppress their own reaction or behavior to the effects. Passive ignoring is when the participants may or may not be aware of the effects and unconsciously do not act upon the aberrant behaviors caused by the AR modality.

Both secondary actors and primary users [P2, P3, S3, S5] exhibit active ignoring. During our interview, we ask participants if there is anything surprising during the desert survival task and how the interaction during that task is different from a regular conversation. P2 remarks that she noticed the AR user tapping on the sides of the AR glasses. However, instead of asking the AR user what she was doing, P2 says she dismissed the action and ignored it "because it's similar to people twirling their hair". She recognizes the power imbalance but effectively chooses inaction. Similarly, S3 and S5 express having noticed the user "being struck by something [they were] seeing" [S5] but brush it off. We find a similar phenomenon in P3 who had to actively "try not to laugh" because she found the filters "funny". This is a unique case in which a primary user actively curbs the effects of the augmented ability to not discomfort the secondary actors. Whether it is for social acceptability or to avoid embarrassment, all four participants made the conscious choice to not act upon aberrant behaviors induced by the AR modality. By choosing *inaction*, they negotiate their own power and effectively maintain the default power dynamic.

On the other hand, participants P4 and S4 demonstrate passive ignoring. During the desert survival task, P4 demonstrates extremely aberrant behavior. As demonstrated in Figure 3, P4 starts leaning into the whiteboard and tilting his body outwards away from the board to face S4 more intently. He also starts to walk to the other side of the board around S4 to align the face filter on S4's face more closely. From a third person's view, this is extremely abnormal behavior that neither helps find items to bring to the desert nor facilitate the communication. However, when asked if there is anything surprising or different from a normal conversation during the interaction task, both P4 and S4 state that nothing was different. In fact, S4 said that "If you were to remove the glasses out of the situation, I think we would have had the same interaction." While S4 is aware of face filters because he asked P4 what he was seeing during the desert survival task, S4 is unconscious of this distinctly abnormal behavior by P4 and does not interrupt P4 to ask him about his behaviors or react to it. S4 is not fully aware of how P4's augmented capabilities is affecting the interaction. Effectively, S4 has unconsciously ignored P4's reaction to the AR modality and maintained the default, unbalanced power dynamic in favor of P4.

Thus, from our study, we find that O'Hagan et al.'s four ways of how coexisting occurs is a notion that could be more nuanced, particularly about VR being considered by participants "as something to ignore" [50]. From our study, we find that *both* primary users and secondary actors ignore the AR modality. P3 actively suppressed her laughter to AR. In addition, ignoring, as we show in our study, is a more subtle cognitive shift that can have either a conscious or unconscious intent behind it. Finally, the inaction caused by ignoring has strong associations with the maintenance of unbalanced user-actor power dynamics.

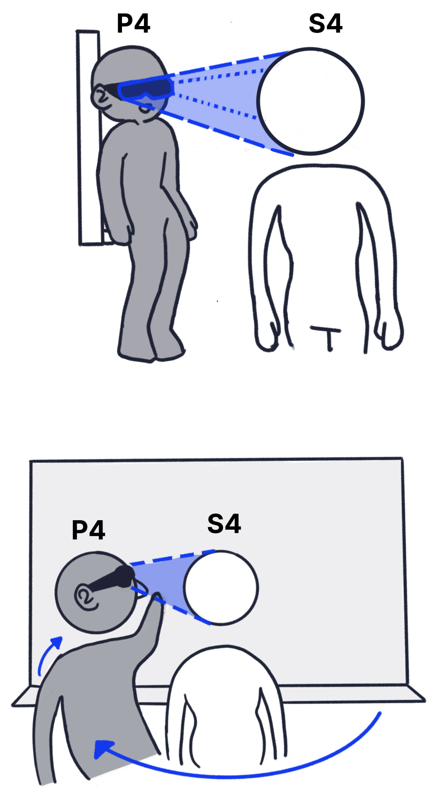


Figure 3: Demonstration of P4's notably awkward behavior. *Top* diagram shows P4 initially leaning into the whiteboard to try and align the face filter on to S4. *Bottom* diagram demonstrates P4 walking around and leaning into the whiteboard to try the face filter at a different angle.

7 DISCUSSION

7.1 Adapting to Each Other

From our study, we find both secondary actors and primary users *adapting* to a newly introduced AR modality and the corresponding changes in their power dynamic. Whether they are conscious or unconscious of these changes, the participants in our study have implicitly accepted the new modality and are evolving around it. This is why they readjust their posture and opt to ignore behaviors. Thus, readjusting and ignoring are mere symptoms of people adapting to a new interaction type.

This also means that both secondary actors and primary users are affected and, in some cases, even actively participating in interactions with augmented reality. Take for example, S1, a secondary actor who readjusts so that P1 can align the face filter better. While S1 may be affected by social factors such as the desire to help P1, effectively, S1 is in fact directly interacting with the face filter. He's adjusting

	Our Study	O'Hagan et al. [50]	Denning et al. Study [10]
Study Setting	Lab	Surveys in-the-wild	In-situ Naturalistic Setting
Device	Spectacles	VR Headsets	Mock-Up AR Glasses
Interaction Studied	Collaborative task between user and secondary actor	User and bystander interactions with VR	Bystander reactions to user sitting in a cafe
Observation Method	Direct observations of participant behavior via video and audio recordings	Surveys of participants, primarily in their home or workplace	Direct in-situ observations
No. of Users	$n=5$	$n=51$	$n=0$ or 1 User was the Researcher
No. Secondary Actors	$n=5$	$n=49$	$n=31$
Participant Concerns			
(1) Abuses of Power by User	Yes	Yes	Yes
(2) Abuses of Power by Secondary Actor	N/A	Yes	N/A
(3) Subtle Form Factor Facilitating Recording	Yes	No	Yes
(4) Self-Presentation Manipulations	Yes	Yes	Yes
(5) Situational Context	Yes	Yes	Yes
Contributions	(1) Observations of secondary actor directly interacting with user, (2) critique of power imbalances induced by design of AR glasses, (3) extends O'Hagan et al.'s VR interaction framework [50] with readjusting and ignoring	(1) Characterization of user and secondary actor interactions in VR, (2) highlights abuses of VR from both parties	(1) Observations of secondary actors in naturalistic settings (2) framework for privacy-mediating technologies
Limitations	Not true stranger-stranger interactions	Interactions in VR do not translate in AR given awareness to physical surroundings	Cannot observe secondary actors interacting with users' virtual augmentations

Table 3: Summarizes differences in study method and findings on users and secondary actors among this study and O'Hagan et al. [50] and Denning et al.'s [10] studies. Our study's main benefit is the direct observation of user and secondary actor behavior.

his own body posture for a virtual augmentation he cannot see. In addition, the secondary actors P2, S3, and S5 all actively decide to not to react or act upon the AR modality despite sensing its presence.

In fact, secondary actors want **ownership** over their augmented self. Secondary actors express negative sentiments at the lack of transparency of the primary user's view and loss of agency over self-presentation because they want to but cannot control how they are represented in the augmented world. Participants express dislike towards discreet recordings because it makes it impossible for them to *own* or control the image of their augmented self. Real-time modifications without recordings are more acceptable because the secondary actors at least have control over that fleeting moment. However, discreet recordings deny the secondary actors' ownership over their augmented selves because shared recordings can trickle down to other people quickly and are hard to restrain.

7.2 Corroborating Results in Previous Works

We find our study method to both replicate and complement preexisting study designs to study user-actor interactions. These comparisons are summarized in Table 3. We find similar issues regarding abuses of power in O'Hagan et al.'s study [50]. We reaffirm that people find recording on cell phones and AR glasses different because of their subtle form factor and ease of recording as described by Denning et al. [10]. We corroborate that sexual exploitation of self-presentation are common concerns for both AR and VR user-actor interactions [10, 50]. We also find that context greatly affects user-actor interactions as did Denning et al. and O'Hagan et al. [10, 49, 50].

Not all VR user-actor interactions translate directly to AR ones. First off, O'Hagan et al. describe abuses in power between users and secondary actors in an almost symmetric fashion [50]. VR users can exploit secondary actors by overlaying sexual content over them and secondary actors can also exploit VR users' blindness towards their physical surroundings to hurt them. However, the secondary actor power abuse is not mirrored with AR glasses because users are aware of their surrounding physical contexts. In addition, we find that certain types of *interrupting* in VR user-actor interactions may be unnecessary in AR user-actor interactions, particularly ones related to physical space. Because AR users are aware of their surroundings secondary actors do not have to find the right timing to "establish presence and location" like VR users [50]. With increasingly more available passthrough technologies that enable users in VR headsets with awareness of physical surroundings like AR glasses, we may soon see interruptions shifting to resemble the findings on AR glasses more. However, further investigation would be required to prove this as overloaded augmentations could create entries of exploits for secondary actors and create the need for AR users to be aware of their physical surroundings.

In addition, we differ with Denning et al.'s finding because the user-actor interactions in our study may not have been *true* stranger-stranger relationships. In Denning et al.'s study secondary actors react primarily indifferently to AR recordings and a third of them respond negatively. In contrast, our study finds the majority of the participants reacting negatively to the recordings. This may be caused by the subtle difference in our study design compared to Denning et al.'s work. In Denning et al.'s work, the user is an *undefined* stranger whom the secondary actors have no context of in a cafe. As a result, approximately two-thirds of the secondary actors are completely unaware of the AR glasses because they're not in an artificial environment to notice them. On the other hand, while four of the five pairs are strangers to the other participant, all secondary actors are aware of the AR glasses because they are in a lab-setting. Thus, while the participants in the lab are strangers to each other, they're strangers in a more trusted setting than Denning et al.'s stranger user. This sentiment was also expressed by some of our participants to have an effect in their responses. Thus, the recording could have come as a greater element of surprise to the participants in our setting because they thought they were in a safe space, but knowing the existence of the recording breached that trust in the space. However, we don't find this to contradict Denning et al.'s study or ours. On the contrary, we think this complements Denning et al.'s findings that *place* and *perception of the recorders* affect what makes recordings acceptable or not.

We also find that our method to observe both primary users and secondary actors in controlled lab settings provides complementary insights to pre-existing literature. While survey methods used by O'Hagan et al. are more comprehensive in the types of scenarios participants face, they are limited in their ability to detect nuanced behavioral changes such as readjusting and distinguish subtle types of interactions such as passive and active ignoring. Survey methods are subject to participants' self-reports while our method can use both self-reports and behavioral analysis to understand interaction changes. In addition, we find it important to have the AR user not use a mockup but a real AR glass with virtual augmentation, even if it is primitive in form. By using a real prototype, we are able to denote the current practical limitations of user-actor interactions such as annoyances caused by darker shades, unstable face filter technology, and short battery life. Wizard-of-oz approaches are also limiting in that we can only analyze the interaction in one-direction as we can only see how the secondary actors react to the primary users. However, user-actor interactions are a two-person interaction and require analysis in both directions from users to secondary actors and secondary actors to users. This is also why we are able to observe subtle negotiations in the form of readjusting and ignoring in our study as well as contrasting sentiments between users and secondary actors.

7.3 Design Implications

For designers and researchers in the field of mixed reality, the study raises awareness of the need to emphasize secondary actors to create a more balanced mixed reality space in which both stakeholders can attain a positive experience. We urge the field to recognize that addressing and equalizing power dynamics is a key factor in designing computing artifacts that promote social connections and well-being. As mixed reality communication continues to evolve and gain traction, these considerations carry significant implications for individuals' social and emotional identities and beliefs. The following are design implications gleaned from our attention to secondary actors:

Direct involvement of secondary actors and users highlighted fundamental design problems in AR Glasses. Through a multidimensional analysis of verbal and nonverbal cues, we demonstrate power imbalances caused by the design of AR glasses and identify factors that amplify them. This method allows us to demonstrate how power dynamics *shift* in user-actor interactions. While previous studies have studied the negative effects of AR glasses and researched technologies to empower secondary actors [10, 40, 49, 50, 70], we focus on demonstrating how secondary actors can negotiate their relative power stance by performing in the virtual space and interacting directly with their virtual embodiment.

Simple features for secondary actors enable positive experiences for both parties. Effectively, S1 readjusts and enhances P1's experience with the simple knowledge that the face filters were not aligning properly. S1's experience is enhanced because they reclaimed some power over the unknown mixed reality situation. Such knowledge or power transfers can be effectively implemented through simple hardware features such as indicator lights or sound alerts. Furthermore, such features would have the added benefit of providing mechanisms for active consent. Thus, future work should focus on creating features that help secondary actors positively interact with and co-exist in mixed reality spaces with users.

Participatory design tasks and role-playing induce nuanced critiques that help understand participants' pre-existing biases and mental models. In assessing and developing effective designs for mixed reality interactions, we advocate for the incorporation of co-design in evaluating ideas. The proposed participatory design task [26, 58] and role-playing, inspired by creative sense-making [9], prove to be a good method to corroborate study results and as a potential method to implicitly understand people's current understanding and mental model of AR glasses. The design task allows an opportunity for participants to self-report issues during the previous interaction task without interview bias. This approach aligns with the concept of 'experience prototyping', which suggests that firsthand experiences with prototypes can unveil intricate insights and unforeseen design implications for prospective conditions [5].

In addition, the task helps identify gaps in certain users' understanding of users and non-users as we see participant S5 struggling to design features for secondary actors. This not only broadens the participants' role as system evaluators but also empowers them as active contributors to future AR experiences that could profoundly affect them. However, note that the resulting redesigns of AR glasses may not contribute to pre-existing literature. Many of the features resulting from these tasks, such as notification systems and projection holographs, have already been researched in the community and often lack nuance in their designs.

8 LIMITATIONS AND FUTURE WORK

Our study has a few limitations. First, since the study requires participants to be in person to try out the AR glasses, most of our participants are in close physical proximity to the institution. This factor may contribute to an age-related bias, potentially affecting the generalizability of the results. It is noteworthy that the participant demographic predominantly comprises younger adults, with 9 individuals aged between 20 and 24 years old and one participant aged 41 years old.

While we manage to have a heterogeneous mix of participants in their technical backgrounds, most participants have limited knowledge of AR technology. They also have not interacted with AR glasses before. Therefore, the findings we generate in the current study are from lay people [6] rather than experts. Past research on automation has shown that people engage with technology differently based on their prior experiences and general digital literacy [46]. Future research should control and examine the effects of participants' levels of digital literacy in AR on their performances and acceptability of the technology.

Furthermore, power imbalances may be more pronounced in real-world settings. In the current study, we randomly assign participants' roles as users and secondary actors and analyze proficiency after the study. This results in having the three participants with the most experience with AR, or the competent and proficient participants, assigned as the secondary users by chance. However, in a real-world context, individuals with more experience with AR are more likely to be primary users given that they have facilitated access [11]. Consequently, users with higher socioeconomic status will have advantageous access for innovative devices which could reinforce pre-existing power imbalances [56, 60]. Future research should thus consider other factors that affect interpersonal dynamics such as social and economic status and cognitive capacity.

Another thing to consider is that when deploying AR glasses at scale to the real world, people's social relationships will impact their experiences. This paper illuminates how AR glasses can modify the quality of social interaction between strangers. Future work should elaborate on our findings and extend the social proximity to close relationships with friends and family members. Previous research has surveyed and explored the relationships between people's comfort level with their social proximity to others [55] in AR interactions.

Given that the current study focuses on dyadic interactions involving AR glasses, it is essential to assess the potential implications of our findings in the context of groups larger than two individuals. Concerns regarding peer pressure and social exclusion should be evaluated to understand the dynamics of AR-mediated interactions among multiple participants. Future studies can incorporate our study methodology with interaction tasks to simulate natural engagement from participants and study how the technology might change social interactions when applied to the real world.

In addition, we have encountered device-specific limitations from the AR glasses. The current AR glasses we use in the experiment have a limited battery life span of 15 minutes when face filters are on, which makes it challenging to generalize interactions with AR glasses of prolonged length. The filter application has a restricted field-of-view that requires participants to face each other at a specific angle. Otherwise, the device will glitch when it fails to capture the targeted face. As a result, the dependency on stable motion limits participants' movements and might influence their perceptions and opinion of the technology. Building on observations in the current study, future work should continue this line and examine the emergence of novel behavior participants generated during long-duration AR social interactions.

9 CONCLUSION

Our exploratory studies comprised participatory design sessions and semi-structured interviews to examine the effects and risks of AR glasses' visual alterations on individuals from a critical perspective. Through an interactive scenario and co-design session, we identified asymmetrical power dynamics between the primary users and secondary actors. Imbalances in power arose from features like dark lenses, discreet recording, and modification capabilities of AR glasses. This one-sided information flow is tied to the lack of informed consent and transparency in the interaction, leaving secondary actors with limited opportunities to opt out. Meanwhile, both participants in the interactions are aware of the presence of separate physical and virtual spaces. They negotiate this space by changing their positioning and filtering what they see to create coexisting realities in both spaces. So while the design of AR glasses is focused on the primary user, we recognize that this creates a virtual space for the secondary actor to navigate, reinforcing an asymmetrical power dynamic that requires the secondary actor to perform in an invisible world.

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REFERENCES

[1] Arthur Aron, Elaine N Aron, and Danny Smollan. 1992. Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of personality and social psychology* 63, 4 (1992), 596. https://doi.org/10.1037/0022-3514.63.4.596
[2] Joseph A Bailey 2nd. 2003. Self-image, self-concept, and self-identity revisited. *Journal of the National Medical Association* 95, 5 (2003), 383.
[3] Liam J Bannon and Pelle Ehn. 2012. Design: design matters in Participatory Design. In *Routledge international handbook of participatory design*. Routledge, United Kingdom, 37–63. https://doi.org/10.4324/9780203108543.ch3
[4] Taryn Bipat, Maarten Willem Bos, Rajan Vaish, and Andrés Monroy-Hernández. 2019. Analyzing the use of camera glasses in the wild. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–8. https://doi.org/10.1145/3290605.3300651

[5] Marion Buchenau and Jane Fulton Suri. 2000. Experience prototyping. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques*. 424–433. https://doi.org/10.1145/347642.347802

[6] Michel Callon. 1999. The role of lay people in the production and dissemination of scientific knowledge. *Science, Technology and Society* 4, 1 (1999), 81–94. https://doi.org/10.1177/097172189900400106

[7] Edith Chen and Louise E Berdan. 2006. Socioeconomic status and patterns of parent–adolescent interactions. *Journal of research on adolescence* 16, 1 (2006), 19–27. https://doi.org/10.1111/j.1532-7795.2006.00117.x

[8] Tom Cole and Marco Gillies. 2022. More than a bit of coding:(un-) Grounded (non-) Theory in HCI. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–11. https://doi.org/10.1145/3491101.3516392

[9] Nicholas Davis, Chih-Pin Hsiao, Kunwar Yashraj Singh, Brenda Lin, and Brian Magerko. 2017. Creative sense-making: Quantifying interaction dynamics in co-creation. In *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition*. 356–366. https://doi.org/10.1145/3059454.3059478

[10] Tamara Denning, Zakariya Dehlawi, and Tadayoshi Kohno. 2014. In situ with bystanders of augmented reality glasses: Perspectives on recording and privacy-mediating technologies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2377–2386. https://doi.org/10.1145/2556288.2557352

[11] Sanjeev Dewan and Frederick J Riggins. 2005. The digital divide: Current and future research directions. *Journal of the Association for information systems* 6, 12 (2005), 298–337. https://doi.org/10.17705/1jais.00074

[12] Stuart E Dreyfus. 2004. The five-stage model of adult skill acquisition. *Bulletin of science, technology & society* 24, 3 (2004), 177–181. https://doi.org/10.1177/0270467604264992

[13] Brian L Due. 2015. The social construction of a Glasshole: Google Glass and multiactivity in social interaction. *PsychNology Journal* 13, 2 (2015), 149–178.

[14] Dominic Furniss, Ann Blandford, and Paul Curzon. 2011. Confessions from a grounded theory PhD: experiences and lessons learnt. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 113–122. https://doi.org/10.1145/1978942.1978960

[15] Simon Gächter, Chris Starmer, and Fabio Tufano. 2015. Measuring the closeness of relationships: a comprehensive evaluation of the'inclusion of the other in the self'scale. *PloS one* 10, 6 (2015), e0129478. https://doi.org/10.1371/journal.pone.0129478

[16] Barney G Glaser, Anselm L Strauss, and Elizabeth Strutzel. 1968. The discovery of grounded theory; strategies for qualitative research. *Nursing research* 17, 4 (1968), 364. https://doi.org/10.4324/9780203793206

[17] John D Gould and Clayton Lewis. 1985. Designing for usability: key principles and what designers think. *Commun. ACM* 28, 3 (1985), 300–311. https://doi.org/10.1145/3166.3170

[18] Ben Green. 2019. "Good" isn't good enough. In *Proceedings of the AI for Social Good workshop at NeurIPS*, Vol. 16.

[19] Jeffrey T Hancock and Jeremy N Bailenson. 2021. The social impact of deepfakes. *Cyberpsychology, behavior, and social networking* 24, 3 (2021), 149–152. https://doi.org/10.1089/cyber.2021.29208.jth

[20] Jeffrey T Hancock, Mor Naaman, and Karen Levy. 2020. AI-mediated communication: Definition, research agenda, and ethical considerations. *Journal of Computer-Mediated Communication* 25, 1 (2020), 89–100. https://doi.org/10.1093/jcmc/zmz022

[21] David Heaney. 2019. HoloLens 2's Field of View Revealed. https://uploadvr.com/hololens-2-field-of-view/

[22] Christian Heath, Jon Hindmarsh, and Paul Luff. 2010. *Video in qualitative research: Analysing social interaction in everyday life*. Sage Publications Ltd London, 55 City Road, London, Chapter Analysing video: Developing preliminary observations, 61–86. https://doi.org/10.4135/9781526435385

[23] Jason Hong. 2013. Considering privacy issues in the context of Google glass. *Commun. ACM* 56, 11 (2013), 10–11. https://doi.org/10.1145/2524713.2524717

[24] Ian Hutchby and Robin Wooffitt. 2008. *Conversation analysis*. Polity, Cambridge, UK. https://doi.org/10.1111/j.1467-9841.2009.00430_4.x

[25] Brigitte Jordan and Austin Henderson. 1995. Interaction analysis: Foundations and practice. *The journal of the learning sciences* 4, 1 (1995), 39–103. https://doi.org/10.1207/s15327809jls0401_2

[26] Finn Kensing and Jeanette Blomberg. 1998. Participatory design: Issues and concerns. *Computer supported cooperative work (CSCW)* 7, 3 (1998), 167–185. https://doi.org/10.1023/A:1008689307411

[27] Rabia Fatima Khan and Alistair Sutcliffe. 2014. Attractive agents are more persuasive. *International Journal of Human-Computer Interaction* 30, 2 (2014), 142–150. https://doi.org/10.1080/10447318.2013.839904

[28] Cory D Kidd and Cynthia Breazeal. 2004. Effect of a robot on user perceptions. In *2004 IEEE/RSJ international conference on intelligent robots and systems (IROS)(IEEE Cat. No. 04CH37566)*, Vol. 4. IEEE, 3559–3564. https://doi.org/10.1109/IROS.2004.1389967

[29] Kangsoo Kim, Mark Billinghurst, Gerd Bruder, Henry Been-Lirn Duh, and Gregory F Welch. 2018. Revisiting trends in augmented reality research: A review of the 2nd decade of ISMAR (2008–2017). *IEEE transactions on visualization and computer graphics* 24, 11 (2018), 2947–2962. https://doi.org/10.1109/TVCG.2018.2868591

[30] Amarolinda Klein, Carsten Sørensen, Angilberto Sabino de Freitas, Cristiane Drebes Pedron, and Silvia Elaluf-Calderwood. 2020. Understanding controversies in digital platform innovation processes: The Google Glass case. *Technological Forecasting and Social Change* 152 (2020), 119883. https://doi.org/10.1016/j.techfore.2019.119883

[31] Myron W Krueger and Stephen Wilson. 1985. VIDEOPLACE: a report from the artificial reality laboratory. *Leonardo* 18, 3 (1985), 145–151.

[32] Olya Kudina and Peter-Paul Verbeek. 2019. Ethics from Within: Google Glass, the Collingridge Dilemma, and the Mediated Value of Privacy. *Science, Technology, & Human Value* 44, 2 (2019), 291–314. https://doi.org/10.1177/016224391879371

[33] J Clayton Lafferty and Alonzo W Pond. 1974. *The desert survival situation: A group decision making experience for examining and increasing individual and team effectiveness.* Human Synergistics, Plymouth, Michigan.

[34] May Jorella Lazaro, Sungho Kim, Jaeyong Lee, Jaemin Chun, and Myung-Hwan Yun. 2021. Interaction Modalities for Notification Signals in Augmented Reality. In *Proceedings of the 2021 International Conference on Multimodal Interaction*. 470–477. https://doi.org/10.1145/3462244.3479898

[35] Sasha Lekach. 2019. Privacy Panic? Snapchat Spectacles raise eyebrows. https://mashable.com/article/snapchat-spectacles-privacy-safety

[36] Tingting Liu, Chris KK Tan, Xiaobing Yang, and Miao Li. 2021. Zhibo gonghui: China's 'live-streaming guilds' of manipulation experts. *Information, Communication & Society* 26, 6 (2021), 1–16. https://doi.org/10.1080/1369118X.2021.1994630

[37] Google LLC. 2022. Glass. https://www.google.com/glass/start/

[38] Inc. Magic Leap. 2022. Magic Leap 2. https://www.magicleap.com/en-us/

[39] Inc. Magic Leap. 2022. Magic Leap 2 Optics Breakthroughs Empower Enterprise AR. https://www.magicleap.com/news/magic-leap-2-optics-breakthroughs-empower-enterprise-ar

[40] Gerard McAtamney and Caroline Parker. 2006. An examination of the effects of a wearable display on informal face-to-face communication. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. 45–54. https://doi.org/10.1145/1124772.1124780

[41] Matthew L Meuter, Amy L Ostrom, Mary Jo Bitner, and Robert Roundtree. 2003. The influence of technology anxiety on consumer use and experiences with self-service technologies. *Journal of Business Research* 56, 11 (2003), 899–906. https://doi.org/10.1016/S0148-2963(01)00276-4

[42] Microsoft. 2022. HoloLens 2. https://www.microsoft.com/en-us/hololens/buy

[43] Hannah Mieczkowski, Jeffrey T Hancock, Mor Naaman, Malte Jung, and Jess Hohenstein. 2021. AI-Mediated Communication: Language Use and Interpersonal Effects in a Referential Communication Task. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW1 (2021), 1–14. https://doi.org/10.1145/3449091

[44] Paul Milgram and Fumio Kishino. 1994. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems* 77, 12 (1994), 1321–1329.

[45] Mark Roman Miller, Hanseul Jun, Fernanda Herrera, Jacob Yu Villa, Greg Welch, and Jeremy N Bailenson. 2019. Social interaction in augmented reality. *PloS one* 14, 5 (2019), e0216290. https://doi.org/10.1371/journal.pone.0216290

[46] Kathleen L Mosier, Linda J Skitka, Mark D Burdick, and Susan T Heers. 1996. Automation bias, accountability, and verification behaviors. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 40. SAGE Publications Sage CA: Los Angeles, CA, 204–208. Issue 4. https://doi.org/10.1177/154193129604000413

[47] Anton Nijholt. 2021. Social Augmented Reality: A Multiperspective Survey. In *2021 Joint 10th International Conference on Informatics, Electronics & Vision (ICIEV) and 2021 5th International Conference on Imaging, Vision & Pattern Recognition (icIVPR)*. IEEE, 1–8. https://doi.org/10.1109/ICIEVICIVPR52578.2021.9564182

[48] Michael A. Norman and Peter J. Thomas. 1991. Informing HCI design through conversation analysis. *International journal of man-machine studies* 35, 2 (1991), 235–250. https://doi.org/10.1016/S0020-7373(05)80150-6

[49] Joseph O'Hagan, Pejman Saeghe, Jan Gugenheimer, Daniel Medeiros, Karola Marky, Mohamed Khamis, and Mark McGill. 2023. Privacy-Enhancing Technology and Everyday Augmented Reality: Understanding Bystanders' Varying Needs for Awareness and Consent. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 6, 4 (2023), 1–35. https://doi.org/10.1145/3569501

[50] Joseph O'Hagan, Julie R Williamson, Mark McGill, and Mohamed Khamis. 2021. Safety, power imbalances, ethics and proxy sex: Surveying in-the-wild interactions between vr users and bystanders. In *2021 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. IEEE, 211–220. https://doi.org/10.1109/ISMAR52148.2021.00036

[51] Hannah RM Pelikan, Yoyo Tsung-Yu Hou, Xiyu Jenny Fu, Leelo Keevallik, Mathias Broth, and Malte F Jung. 2022. Interaction Prototyping With Video: Bridging Video Interaction Analysis & Design. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–4. https://doi.org/10.1145/3491101.3503765

[52] Patrick Reipschläger and Raimund Dachselt. 2019. Designar: Immersive 3d-modeling combining augmented reality with interactive displays. In *Proceedings of the 2019 ACM International Conference on Interactive Surfaces and Spaces*. 29–41. https://doi.org/10.1145/3343055.3359718

[53] Patrick Reipschlager, Tamara Flemisch, and Raimund Dachselt. 2020. Personal augmented reality for information visualization on large interactive displays. *IEEE Transactions on Visualization and Computer Graphics* 27, 2 (2020), 1182–1192.

https://doi.org/10.48550/arXiv.2009.03237

[54] Juan Sebastian Rios, Daniel John Ketterer, and Donghee Yvette Wohn. 2018. How Users Choose a Face Lens on Snapchat. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing* (Jersey City, NJ, USA) *(CSCW '18)*. Association for Computing Machinery, New York, NY, USA, 321–324. https://doi.org/10.1145/3272973.3274087

[55] Jan Ole Rixen, Teresa Hirzle, Mark Colley, Yannick Etzel, Enrico Rukzio, and Jan Gugenheimer. 2021. Exploring augmented visual alterations in interpersonal communication. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–11. https://doi.org/10.1145/3411764.3445597

[56] Laura Robinson, Jeremy Schulz, Aneka Khilnani, Hiroshi Ono, Shelia R Cotten, Noah McClain, Lloyd Levine, Wenhong Chen, Gejun Huang, Antonio A Casilli, et al. 2020. Digital inequalities in time of pandemic: COVID-19 exposure risk profiles and new forms of vulnerability. *First monday* 25, 10 (2020). https://doi.org/10.5210/fm.v25i7.10845

[57] Rufat Rzayev, Susanne Korbely, Milena Maul, Alina Schark, Valentin Schwind, and Niels Henze. 2020. Effects of position and alignment of notifications on AR glasses during social interaction. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. 1–11. https://doi.org/10.1145/3419249.3420095

[58] Douglas Schuler and Aki Namioka. 1993. *Participatory design: Principles and practices*. CRC Press, Boca Raton, Florida. https://doi.org/10.1201/9780203744338

[59] Ayoung Seok and Yongsoon Choi. 2018. A study on user experience evaluation of glasses-type wearable device with built-in bone conduction speaker: focus on the zungle panther. In *Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video*. 203–208. https://doi.org/10.1145/3210825.3213569

[60] Seung-Yoon Shin, Dongwook Kim, and Soon Ae Chun. 2021. Digital divide in advanced smart city innovations. *Sustainability* 13, 7 (2021), 4076. https://doi.org/10.3390/su13074076

[61] Dean Keith Simonton. 2004. Film awards as indicators of cinematic creativity and achievement: A quantitative comparison of the Oscars and six alternatives. *Creativity Research Journal* 16, 2-3 (2004), 163–172. https://doi.org/10.1207/s15326934crj1602&3_2

[62] Richard Skarbez, Missie Smith, and Mary C Whitton. 2021. Revisiting milgram and kishino's reality-virtuality continuum. *Frontiers in Virtual Reality* 2 (2021), 647997. https://doi.org/10.3389/frvir.2021.647997

[63] Lens Studio Snap Inc. 2018. 2D Objects. https://docs.snap.com/lens-studio/references/templates/face/2d-objects/

[64] Spectacles Snap Inc. 2019. About spectacles (2021). https://support.spectacles.com/hc/en-us/articles/360058508132-About-Spectacles-2021-

[65] Wen-Jie Tseng, Elise Bonnail, Mark McGill, Mohamed Khamis, Eric Lecolinet, Samuel Huron, and Jan Gugenheimer. 2022. The Dark Side of Perceptual Manipulations in Virtual Reality. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 612, 15 pages. https://doi.org/10.1145/3491102.3517728

[66] Marco Viola. 2022. Seeing through the shades of situated affectivity. Sunglasses as a socio-affective artifact. *Philosophical Psychology* 0, 0 (2022), 1–25. https://doi.org/10.1080/09515089.2022.2118574 arXiv:https://doi.org/10.1080/09515089.2022.2118574

[67] Julius Von Willich, Markus Funk, Florian Müller, Karola Marky, Jan Riemann, and Max Mühlhäuser. 2019. You invaded my tracking space! using augmented virtuality for spotting passersby in room-scale virtual reality. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 487–496. https://doi.org/10.1145/3322276.3322334

[68] Erich H Witte. 2007. Toward a group facilitation technique for project teams. *Group Processes & Intergroup Relations* 10, 3 (2007), 299–309. https://doi.org/10.1177/1368430207078694

[69] Katrin Wolf, Albrecht Schmidt, Agon Bexheti, and Marc Langheinrich. 2014. Lifelogging: You're wearing a camera? *IEEE Pervasive Computing* 13, 3 (2014), 8–12. https://doi.org/10.1109/MPRV.2014.53

[70] Marty J. Wolf and Frances Grodzinsky. 2015. Augmented Reality All Around Us: Power and Perception at a Crossroads. *ACM Computers and Society* 45, 3 (2015), 126–131. https://doi.org/10.1145/2874239.2874257

[71] Channel XR. 2022. Magic Leap 2. https://channelxr.com/collections/magic-leap-2

[72] Yaxing Yao, Huichuan Xia, Yun Huang, and Yang Wang. 2017. Privacy mechanisms for drones: Perceptions of drone controllers and bystanders. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 6777–6788. https://doi.org/10.1145/3025453.3025907

[73] Nick Yee and Jeremy Bailenson. 2007. The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. *Human Communication Research* 33 (07 2007), 271 – 290. https://doi.org/10.1111/j.1468-2958.2007.00299.x

[74] Leslie A Zebrowitz and Joann M Montepare. 2008. Social psychological face perception: Why appearance matters. *Social and personality psychology compass* 2, 3 (2008), 1497–1517. https://doi.org/10.1111/j.1751-9004.2008.00109.x

[75] Feng Zhou, Henry Been-Lirn Duh, and Mark Billinghurst. 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. In *2008 7th IEEE/ACM International Symposium on Mixed and Augmented Reality*. IEEE, 193–202. https://doi.org/10.1109/ISMAR.2008.4637362