In Focus, Out of Privacy: The Wearer's Perspective on the Privacy Dilemma of Camera Glasses

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Figure 1: Person inconspicuously tapping on the side of camera glasses (StableDiffusion, 2023)

ABSTRACT

The rising popularity of camera glasses challenges societal norms of recording bystanders and thus requires efforts to mediate privacy preferences. We present the first study on the wearers' perspectives and explore privacy challenges associated with wearing camera glasses when bystanders are present. We conducted a micro-longitudinal diary study ($N = 15$) followed by exit interviews with existing users and people without prior experience. Our results show that wearers consider the currently available privacy indicators ineffective. They believe the looks and interaction design of the glasses conceal the technology from unaware people. Due to the lack of effective privacy-mediating measures, wearers feel emotionally burdened with preserving bystanders' privacy. We furthermore elicit how this sentiment impacts their usage of camera glasses and highlight the need for technical and non-technical solutions. Finally, we compare the wearers' and bystanders' perspectives and discuss the design space of a future privacy-preserving ecosystem for wearable cameras.

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CCS CONCEPTS

• **Security and privacy** → **Social aspects of security and privacy**; *Privacy protections*; • **Human-centered computing** → Empirical studies in ubiquitous and mobile computing.

KEYWORDS

camera glasses, smart glasses, wearables, privacy, wearer's perspective

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1 INTRODUCTION

Personal recording devices with integrated cameras and multimedia capabilities have become ubiquitous. These devices come in forms ranging from action and dashboard cameras to body-worn life-logging devices. They are predominantly used to capture, archive, and share day-to-day activities [6]. Wearable camera glasses, a specific form of *smart glasses*, are a novel addition to the landscape, allowing wearers to capture photos and record videos from a first-person perspective. Steve Mann's EyeTap project [40] pioneered

Figure 2: Google Glass (left), Snap Spectacles (middle), and Ray-Ban Stories (right)

camera glasses, and Google popularized them [21]. While the earlier models had a futuristic and easily identifiable design, today's generation of camera glasses seamlessly integrates cameras into conventional eyeglass frames, making them indistinguishable in public.

The Google Glass project challenged social norms and privacy legislation. Wearers were attacked [54] because of the expectation that they would record videos without consent. In contrast to this earlier design, wearers of the new and unobtrusive generation of camera glasses can discreetly capture photos and videos – exasperating tensions around perceived privacy norms. Previous research in this domain primarily focused on safeguarding the privacy of bystanders [14, 23, 36, 51], i.e., various ways of protecting the privacy interests of individuals who are captured – possibly unintentionally – without their knowledge and, consequently, their consent. Many of these works implicitly assume that the wearers disregard others' privacy needs.

The privacy impact of camera glasses is largely based on the choices made by the person wearing them. As such, it is crucial to examine the wearers' perspective. In this work, we aim to understand how wearers perceive others' privacy, their emotions in social situations, the intrinsic and extrinsic social pressures they experience, and the measures they take to mitigate the impact on others' privacy.

To this end, we conducted a micro-longitudinal diary study with $N = 15$ participants. Over two weeks, participants wore camera glasses and documented their privacy-related experiences firsthand. To capture these experiences in situ with minimal effort, we offered a multi-modal way to share impressions on-the-go via an instant messenger. Finally, we conducted semi-structured exit interviews to understand the wearers' perspectives and contextualize their experiences.

Our findings indicate that: a) Wearers feel an inherent burden to protect the privacy of bystanders; b) Wearers tend to put themselves in the shoes of the bystanders to make privacy decisions; and c) Wearers want better privacy indicators to relieve themselves from the negative stigma of potentially not conforming to the social norms on recording, i.e., without a reliable way for others to determine whether or not the device is recording, wearers risk continuous suspicion of recording in socially inappropriate moments.

This paper provides an overview of the wearers' needs and explores the possible tools for socially responsible device use. Our study also reveals a fundamental technological gap between wearers and bystanders: Both parties make implicit assumptions about the other party's motivation, needs, and values. Currently, no technology that mediates privacy preferences and enables privacy-preserving capturing of everyday situations is available to them.

2 BACKGROUND

2.1 Ray-Ban Stories

We selected the Ray-Ban Stories camera glasses for this study as they are easily accessible for purchase by the general public despite not being officially available in many markets.

The Ray-Ban Stories smart glasses were developed by Meta in cooperation with Ray-Ban [1] and were made commercially available in 2021. At the time of purchasing, they were priced at 329€. The glasses sport dual 5MP cameras, which allow wearers to capture photos and videos from a first-person perspective with a button press on the temple. The button press activates an audio cue to provide feedback to both wearers and bystanders. Photos are shot with a resolution of 2592×1944 pixels and videos with 1184×1184 pixels at 30 fps for up to 30 seconds, with a possible extension to 60 seconds [52]. A hard-wired white *capture LED* operates as a privacy indicator and alerts bystanders whenever a capture occurs. We include a video of a person interacting with the Ray-Ban Stories in the supplementary material. The glasses come with 4GB of onboard storage, resulting in a maximum capture capacity of 500 photos or 30 full-length videos. The glasses have a physical kill switch for the camera, allowing wearers to turn it off. They also incorporate open-ear speakers and an array of microphones, enabling audio streaming and voice transmission.

In contrast to previously available smart glasses, the Ray-Ban Stories have few features that distinguish them from regular sunglasses. Figure 2 shows a comparison between the Ray-Ban Stories and two established smart glasses, the Google Glass[1] and the Snap Spectacles[2]. It is evident that the Ray-Ban Stories were intended to look like regular sunglasses. The position of the camera lenses on the Ray-Ban Stories blends in with the design elements used in traditional glasses, as depicted in Figure 3, making it difficult to tell apart smart from non-smart models.

The Facebook View app [2, 3] is designed to work alongside the glasses, enabling wearers to transfer their captured images to their mobile phones. The app enables additional functionality for editing captures, adding effects, and uploading them to social media. However, the app requires wearers to log in to a Meta account.

[1] https://www.google.com/glass
[2] https://www.spectacles.com

(a) Regular Ray-Ban Sunglasses

(b) Ray-Ban Stories Camera Glasses

Figure 3: Resemblance of regular non-smart *Ray-Ban* sunglasses to *Ray-Ban Stories* camera glasses.

2.2 Privacy Indicators

Privacy indicators are visual or audible cues that serve as feedback mechanisms to inform both primary and secondary users about data that is collected and processed by a system [33], e.g., a light or a snapshot sound. They help users gauge the level of privacy protection and enable them to make informed decisions, thereby enhancing transparency and trust. There are two types of privacy indicators: direct and indirect. Direct indicators provide explicit privacy information, while indirect indicators imply privacy-related information through subtle cues.

3 RELATED WORK

3.1 Real-World usage of Wearable Recording Devices

The past decade has brought significant advancements in the realm of wearable cameras, both in terms of form factor and functionality, ranging from lifelogging devices to camera glasses. While prior research has delved into the usage of these devices in the real world, most of it has been centered around targeted applications or domains [39, 46, 57]. To provide a more diverse overview of wearable cameras, researchers have examined the usage and implications of wearable cameras in the real-world [10, 31, 47, 56]. Hoyle et al. [26] investigated how people use and perceive lifelogging devices by means of an in situ study. They found that people are concerned about the privacy of bystanders and prefer to manage privacy directly on-site by physically controlling image collection in real time. Iqbal and Campbell [28] discussed theoretical privacy and ethical issues associated with the Ray-Ban Stories. Bipat et al. [6] analyzed the motivation behind why and in which scenarios people use camera glasses. They discovered that people predominantly wear camera glasses during social interactions and while being physically active. Moreover, they reported that camera glass usage is influenced by both personal and societal preferences. People tend to use camera glasses more often for outdoor recording while also taking societal norms into account when capturing content e.g., assessing the appropriateness of recording the scene.

3.2 Bystander Perception of Wearable Recording Devices

Privacy of bystanders has been keenly researched in literature [14, 23, 32, 35, 50], with researchers investigating bystanders' privacy perceptions and attitudes towards smart glasses. Denning et al. [14] explored the privacy perspectives of bystanders towards augmented reality glasses and found them to be "split between indifferent and negative." They also noted that many bystanders indicated a desire to be asked for consent and to block recording devices. Koelle et al. [32] studied the social acceptability of "data glasses" and how the usage of these glasses is perceived by peers. They found user attitudes to be more critical about glasses than other portable devices. They, therefore, recommended only specialized task-based usage of the glasses.

3.3 Privacy Notices in Recording Devices

Camera glasses employ a capture LED, which is advertised as a privacy indicator for people. The LED lights up to let bystanders know that the person wearing the glasses is capturing a photo or video. Portnoff et al. [45] examined the effectiveness of using an LED as a privacy indicator in the context of webcams and reported that less than 50% of participants noticed the LEDs during computer-based tasks and less than 5% noticed the LEDs during written tasks. Based on their findings, they concluded that LEDs are ineffective privacy indicators. Also, in their paper [33], Koelle et al. pointed out that LEDs lack noticeability, understandability, security, and trustworthiness, rendering them ineffective design choices for privacy notices.

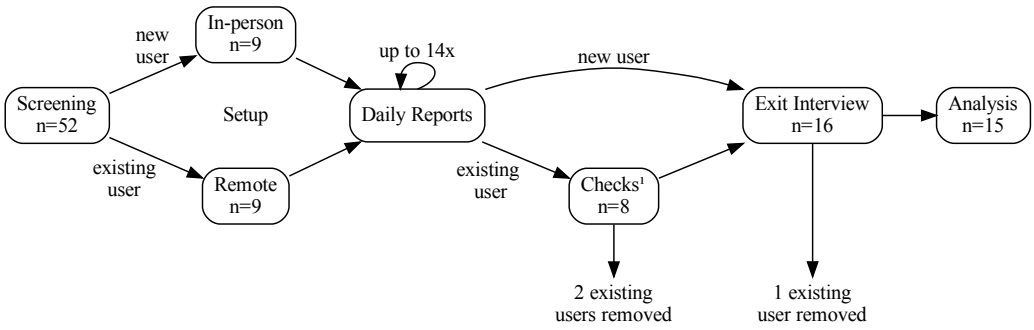

Figure 4: Overview of our study workflow including number of participants at each stage. [1]) Checks were introduced for existing (remote) users, after a suspected fraud attempt during the first interview. Further two users could not prove that they owned the glasses during those checks.

3.4 Design Directives for Privacy

To preserve bystanders' privacy, researchers have devised ways for people to communicate their privacy preferences towards wearable recording devices. Krombholz et al. [11, 35] looked into privacy-enhancing technologies in literature and came up with a set of properties to communicate privacy preferences to Google Glass. As a follow-up [36], they presented three abstract privacy-enhancing technologies in the form of a privacy app, privacy fabric, and privacy bracelet to help people protect their privacy.

In summary, bystander attitudes and behavior in relation to recording devices have been keenly researched in literature. Bystanders have expressed the need to preserve their privacy. While most recording devices make use of LEDs to notify bystanders, LEDs are bad privacy indicators, and bystanders often do not understand what they signify. Most of the design directions proposed in existing literature put the onus of protecting themselves on the bystanders. However, in the real world, the privacy of bystanders is heavily reliant on the privacy outlook and attitude of the person wearing the camera glasses. To fill this gap in the literature, we build upon previous work from Bipat et al. [6] and focus extensively on the privacy perceptions and behavior of the wearer of the camera glasses through a qualitative study.

4 METHODOLOGY

To extend the body of work, we focus on the people using camera glasses, as they are often responsible for privacy-relevant decisions. This approach stands in contrast to previous work, which primarily investigated the bystanders' perspective. Our approach is exploratory in nature since little is known about the topic of interest in this specific context. We used the following questions to guide our investigations:

- Are users aware of the privacy implications of wearing the Ray-Ban Stories sunglasses?
- How does wearing Ray-Ban Stories affect users' privacy behavior?
- What are the privacy needs of the wearers?

At the start of the study, Ray-Ban Stories were the most commercially available camera glasses and were sold in Australia, Canada, Ireland, Italy, the UK, and the U.S. [1]. Thus, we chose these glasses to conduct our study of wearable recording devices. The Ray-Ban Stories perfectly represent the device class as they are primarily focused on the recording task and lack additional "smart" functionality such as an integrated display like Google Glass or Snap Spectacles 3.

In order to collect data over an extended amount of time and to minimize the Hawthorne Effect [41], we conducted a diary study. We chose the diary method to get an enhanced understanding of the day-to-day privacy perceptions of the wearer. This also allowed new users to get familiar with the technology and provided them with a realistic experience of someone who freshly acquired camera glasses, improving the ecological validity of our study. We let the participants record their daily experiences at their convenience to minimize frustration and fatigue [8]. The diary study additionally enabled us to capture participants' observations in greater contextual detail [43]. Figure 4 depicts our full study setup in detail.

4.1 Recruitment

To cover the full spectrum of wearers' experiences, we gathered data from both existing users and people who first experienced using the glasses during our study. We recruited participants between October 2022 and August 2023 via various channels.

Existing users. To recruit existing users, we advertised our study in the Ray-Ban Stories Subreddit *r/RayBanStories*[3]. At the time of recruitment, this forum had over 1200 subscribers. We expected most of these subscribers to be active users, as most posts on this forum are about users' experiences with glasses or their intention to acquire one. Our advertising post contained the participation requirements (most noteworthy, being an active user of the glasses), the tasks participants would need to perform, the monetary compensation, and the primary authors' contact details. A community moderator approved our post. In addition, we used snowball sampling, a method that has proven to be effective when recruiting users of a specific technology, as they often get introduced to it by an acquaintance and, therefore, know fellow users [30, 44, 48]. We

[3]https://www.reddit.com/r/RayBanStories

recruited seven users via Reddit and one via snowball sampling. We stopped recruiting when only few new topics came up during the analysis, i.e., when we reached data saturation for the given group. Since we expected most of the community members, similar to general Reddit users [49], to be from outside the EU, we designed our study to be fully remote for existing users. While conducting the very first interview with an existing user, the interviewer noticed that the participant was unfamiliar with the glasses and their functionality. Upon questioning, they were unable to provide evidence that they possessed the glasses. Due to this, the interviewer became suspicious of whether the person actually owned or ever used the glasses. After reviewing the recording with the rest of the research team, doubts solidified, and we decided to exclude the participant from the study. The participant was still fully compensated for their time, but we added additional checks for subsequent participants. Thereafter, we required existing users to bring their glasses to the final interview and show them to the interviewer. Two more participants could not meet this criterion, resulting in them not receiving compensation because we did not conduct the interview this time. The final dataset comprises $N = 6$ existing users.

New users. For new users, it was necessary to physically meet with participants to lend them a pair of glasses they could use for the study. We purchased two pairs of Ray-Ban Stories with identical form factors, one with a black frame and the other with navy blue. We opted for the black model, as it resembled regular sunglasses the most, while the blue model featured the most noticeable camera lenses. We posted flyers advertising the study around the University campus and city center. Potential participants filled out a screening survey, which included demographic data and consent questions. The participants needed the official Facebook View app and a Meta account to connect with and operate the glasses (see Section 2). The app is geo-locked to markets where the glasses are officially sold, so we had to side-load it onto Android phones. Due to the lack of a similar easy technique for iOS, we could not accept iPhone users. For the Meta account, we set up two dummy accounts for participants without a personal account or unwilling to use it. We recruited $N = 9$ participants for this user group. Again, we stopped recruiting when we reached saturation.

Table 1 shows demographic information of the final group of participants who completed the study. We recorded age as a range in order to protect our participants' privacy. We also assessed how apprehensive our participants were to other people's opinions of them, using the brief fear of negative evaluation (BFNE) scale by Learly [38].

Table 1: Participant Demographics (after removals)

Participant ID	Existing user	Age bracket	Gender	Residence	Highest education	BFNE score [38]	Interview translated
E1	●	30-39	M	United States	University	20	
E2	●	30-39	M	France	University	36	
E3	●	30-39	M	Ireland	University	43	
E4	●	30-39	M	United States	University	25	
E5	●	30-39	M	United States	University	40	
E6	●	18-29	F	United States	University	24	
N1		18-29	F	Germany	High school	43	
N2		18-29	F	Germany	University	20	
N3		18-29	M	Germany	High school	56	●
N4		18-29	F	Germany	University	49	●
N5		18-29	F	Germany	High school	46	●
N6		18-29	F	Germany	High school	21	●
N7		18-29	M	Germany	University	31	
N8		18-29	F	Germany	University	n/a	
N9		18-29	M	Germany	High school	n/a	

4.2 Data Collection

We opted for a diary-based micro-longitudinal study. In contrast to an interview-only study, this allowed collecting data *in situ* as soon as it is available. To collect sufficient data points, we asked participants to use the glasses as often as possible during their 14-day study period. We did not expect participants to wear and use the glasses daily, as the tainted sunglasses are unpleasant to use indoors or in low-light conditions. For our main recruitment region in Western Europe, we expected sunny conditions approximately 50% of the time, leaving seven days of sunglasses usage over the 14-day study period. Additionally, the time window granted new users enough time to acquaint themselves with the technology. During this time, we asked participants to write one diary entry daily about their experiences and associated feelings. For the daily reports, we set up an online survey comprising four questions to guide participants to the topics we were most interested in:

- How often did you use the Ray-Ban glasses during the day?
- How did you feel while using the glasses?
- How do you think people around you perceive you?
- Can you tell us about any situation that made you rethink/re-evaluate the way you use the glasses? What actions did you take to fix this?

For each participant, we set up a separate instant messaging conversation with a research team member to send out initial instructions and periodic (opt-in) reminders to use the glasses and write diary entries. The responsible researcher monitored the diary entries. If participants misunderstood the questions or if their entries were very short, we clarified what kind of experiences we were interested in and encouraged them to go into more detail.

At the end of the two weeks, we invited participants to an exit interview either online via Zoom or in person at our lab. During these interviews, we dug deeper into our participants' experiences with the glasses. We based our follow-up questions on their diary entries to further explore topics we deemed especially interesting and relevant. To facilitate this, the interviewer revisited all diary entries by the participant and took notes, which then served as a guideline for the interview. We include our semi-structured interview guideline in Table 2 in the Appendix.

Participants received a base compensation of 50€ if they completed the 14-day period and took part in the exit interview. To motivate participants to use the glasses daily, we compensated them with an additional 2€ per diary entry, resulting in a maximum of 78€ for the entire study. We also encouraged our participants to write a diary entry even if they did not use the glasses that day, simply stating this fact in the first question of the daily report. This

served the purpose of keeping participants engaged with the topic and having them continuously reflect on their experiences.

4.3 Pilot Test

We conducted two pilot testing sessions to validate our approach. We recruited two acquaintances of the primary researchers that fit our criteria for the *new user* group. We chose to pilot test the study with new users, as we expected them to have a higher entry barrier compared to existing users who are already familiar with camera glasses. Both pilot testers used the provided glasses for 14 days, keeping a diary throughout this period. The setup used for pilot testing corresponded to the one we used during our study. Based on the pilot interviews, we adapted two items of the daily questionnaire, as participants were confused by the phrasing.

4.4 Qualitative Data Analysis

After collecting the data, we employed an inductive qualitative analysis approach that follows the thematic analysis process by Braun and Clarke [7]. We chose this approach since it has proven to be effective for exploratory research such as ours [6, 16, 44]. For most participants, a GDPR-compliant third-party service transcribed the interviews orthographically. We manually transcribed the interviews of participants who did not consent to third-party data processing. Also, a native-speaking researcher translated all transcripts of interviews and diary entries from German-speaking participants into English. The two primary researchers independently coded the same two interviews following the open coding approach. During the coding process, they referred to the corresponding diary entries for context. The two researchers then met and merged their codes to develop the initial codebook. They applied axial coding to structure the codes and made them easier to work with. Using the resulting codebook, the two researchers independently coded two further interviews. After this step, the inter-rater reliability based on Krippendorff's Alpha [24] over the last two interviews was $\alpha = 0.44$, indicating moderate agreement [37]. Both researchers discussed and resolved disagreements and modified the codebook accordingly. Following this, the same two coders independently coded two more interviews. Krippendorff's Alpha for these two interviews resulted in $\alpha = 0.65$, indicating substantial agreement [37]. The team deemed this sufficient to split the remaining nine transcripts between the two coders. After both researchers had coded two of their respective interviews, they discussed the findings and started developing the themes. Finally, both coders processed their remaining interviews, and the entire research team met to refine the themes and discuss how to report the findings. The final codebook can be found in Figure 8 in the Appendix.

4.5 Ethical Considerations

Our university's ethical review board (ERB) approved our study design. Throughout the study, we minimized the collection of personally identifiable information (PII) and limited the number of people with access to non-anonymized data. We stored and processed all our data in line with the GDPR. We asked for consent to side-load the companion 'Facebook View' app in the consent form. During the initial setup, we explained the need and functioning of the app. We informed our participants that they could withdraw their initial consent at any time without consequences. Participants had the opportunity to ask us any questions about the study during or after the study period. We clarified to all the participants that we would not view any photos they took with the glasses. We asked them to use the established instant messaging channels if they explicitly wanted to share images with us. After the study, we instructed participants in the *new user* group to factory reset the glasses before returning them, thus deleting all data and pictures on the internal storage. Nonetheless, we also reset all pairs of glasses before handing them out again.

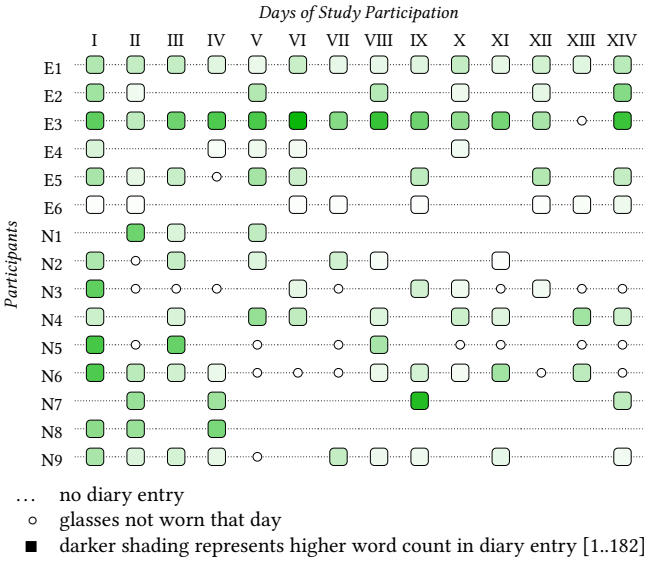

Figure 5: Participants' responses in the diary study by day and word count. These entries, together with the exit interviews, comprised the data corpus for our thematic analysis.

5 RESULTS

We performed a thematic analysis on the data we collected as described in Section 4. Our corpus consists of both diary entries and transcripts of the exit interviews. Out of 129 diary entries submitted by participants, 25 were null reports, indicating that the participants did not wear the glasses on those days. On average, participants submitted 6.9 diary entries (SD = 3.3) over the 14-day study period. Figure 5 depicts each participant's diary entries by day and content length. Exit interviews lasted between 11m34s and 48m28s (Mean = 30m14s, SD = 10m59s) for a total of 454 minutes.

Throughout the following sections, we use E1-6 as an identifier for existing users and N1-9 for new users, respectively. For interviews not held in English, we translated the transcripts and the diary entries into English prior to coding. We also use these translations as direct quotes throughout the paper. Omissions and edits for brevity, readability, and context are denoted with square brackets.

The following sections are structured along the final themes we established during the analysis. Figure 6 illustrates how these themes are interrelated.

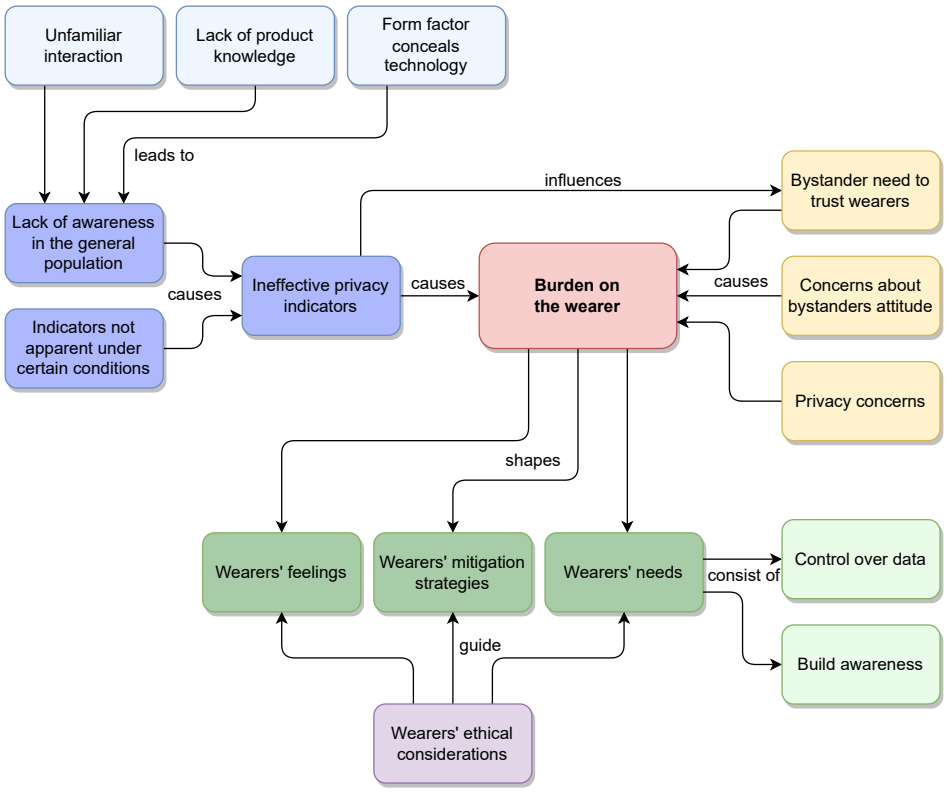

Figure 6: Schematic diagram of our final themes, illustrating the relations between them.

5.1 Ineffective Privacy Indicators

The most prominent topic during our study was privacy indicators and their perceived ineffectiveness by the wearers. All participants were aware of the light indicator on the front side. Figure 7 illustrates how the LED turns on during recording (supplemental material contains a video version). Some also mentioned the trigger sound, which would be played when taking a picture or recording a video, as an additional privacy indicator. Both indicators were perceived as inadequate and ineffective when it came to notifying bystanders. First, they are unreliable under certain conditions, and second, they are not necessarily understood by others.

5.1.1 Indicators not Apparent under Certain Conditions. First of all, our participants reported that the privacy indicators would fail to convey their message under certain conditions. These conditions most notably include sunny weather, which represents the main justification for sunglasses in the first place. Especially while outside and in nature, wearers thought it would be difficult to see the (rather faint) white light due to reflection and sun glare. N4 explained the LED would not be noticeable "*if you're at a lake, where the pond is glittering and stuff.*"[N4]

Furthermore, wearers did not trust the privacy indicators to be sufficiently visible and audible in crowded environments. Our participants reported often wearing the glasses in such circumstances. They expressed their disbelief that a short glimpse of the glasses' LEDs in a dynamic, crowded environment - or the brief tone next to a vivid conversation is noticeable enough. N3 stated: "*The length of time you look at a person is crucial. So, how closely you look.*"[N3]

Additionally, participants criticized the weak LED as inappropriate for longer distances.

> "*The LED light is very weak. [...] If people are a little bit far away from you, then you can take pictures of anything that you want.*"[N2]

Finally, the LED indicator could be covered accidentally by longer hair. Our participants reported similar experiences when they were wearing hats or any other headgear.

Actively Disabling Indicators. Some participants also explain how malevolent wearers could disable the privacy indicators. None of our participants reported ever doing it themselves. However, they showed awareness of low-tech solutions like covering up the LED or turning the glasses' volume down.

> "*if you look on the Internet, you can see that some clever people have found ways of hiding the LED signal on the glasses by putting on tape or something like that.*"[E2]

5.1.2 Lack of Awareness in the General Population. Besides the environmental conditions in which privacy indicators would fail, our participants shared their impression of a lack of awareness in the general population. This was the case for both our new and existing users. Even if bystanders would notice the glasses or see

(a) Inactive **(b) Active**

Figure 7: Depiction of the glasses before and during a recording. The active LED indicator is magnified.

the light, wearers did not expect them to recognize them as camera glasses or interpret the light as an ongoing recording. We identified three main factors for this perceived lack of awareness:

(1) **Lack of product knowledge.** Throughout the time of the study, Ray-Ban Stories were not available in the country where the majority of our *new users* were recruited from. While this reduces interference from prior knowledge, bystanders have also most likely never seen this product before. Thus, the wearers did not expect bystanders to be able to distinguish the camera glasses from regular shades, unless they were used atypically, e.g., indoors. Similarly, our participants did not expect people to associate the white light with a recording. They reported that for them, a red colored light would serve this purpose much better. Most wearers attribute the lack of knowledge to an absence of ads or discussion about the product in any media.
Likewise, existing users reported a similar perceived lack of knowledge about the product, even in countries where the glasses were already available for purchase. These participants mainly described themselves as early adopters and did not expect others to keep up with the latest technology as closely.

> "*Personally, I know that it lights up when you record something, but they don't know that. Because not everyone knows such glasses*" N4

(2) **Form factor conceals technology.** All our participants agreed that bystanders would first and foremost identify the Ray-Ban Stories as regular sunglasses due to the novelty. They would also fail to recognize the camera in the frame. E5 explains: "*To know that it has a camera, very few people even try to look for that because they don't expect glasses to have cameras.*" E5 In contrast to smart and camera glasses that were introduced in the past (e.g., Google Glasses or Snap Spectacles), the Ray-Ban Stories have no distinguishing features that let them stand out among sunglasses. Our participants explained how the regular symmetrical design of the glasses gave no hint about the integrated technology. The camera lenses are incorporated into the frame in a way that corresponds to well-known models of regular Ray-Ban sunglasses.

> "*Especially if I pick the black frame, the camera just merges with the frame and it could just be like a design element rather than an actual camera.*" E5

(3) **Unfamiliar interaction.** Another major factor contributing to the perceived lack of awareness in bystanders was the unfamiliar interaction patterns of taking pictures and recording videos with the glasses. As described in Section 2, the wearer can trigger a recording by pressing the button located on one side of the glasses' frame. Our participants expressed that this interaction was unknown to many people in general. They did not expect bystanders to associate this with a recording.
Many wearers compared the interaction to a smartphone. When taking a picture, users typically hold the phone to aim and look at the screen simultaneously before tapping to shoot. This interaction is familiar to most people and is easily recognizable as an act of recording, in our participants' opinion.

> "*I'm not walking about with a phone taking pictures, so people can't duck out of the way or hide. I'm walking about with these glasses, and people have no idea what I'm doing.*" E3

Using a smartphone is also perceived as much more of an active task, as the benign user has to first take out their

phone, unlock it, aim at the photo motive, and only then take a picture. In comparison, using the glasses was perceived as a more passive act, in that the glasses would constantly sit on a person's face, and bystanders could not perceive whether they were currently recording or not.

> "*When you use a smartphone, you're acting, while with the glasses, you're passive. You simply have them on.*"[N3]

5.2 Burden on the Wearer

Our results show that the wearers believe the currently implemented privacy indicators do not effectively inform bystanders about ongoing recordings. Our participants felt like the current technology did not sufficiently aid them in addressing security and privacy issues surrounding camera glasses. Therefore, they were under the impression that the burden of protecting other people's privacy was entirely on them as the wearer. We delved deeper into these perceptions and refined our findings into three themes, summarized below.

5.2.1 Privacy Concerns. The wearers were aware of the privacy implications of recording people. Most notably, concerns were voiced about faces. Our participants considered them an especially identifiable physical aspect of bystanders and worthy of additional scrutiny.

> "*I was really careful not to take photos of people's faces, strangers that I don't know, even friends, though. I didn't want to necessarily take photos of their faces. I was trying to just take photos of anything that doesn't have any sensitive data, like the street, community place, places where nothing would happen, or just the stores, things that you're just allowed to take photos of with your phone.*"[N2]

While discussing their privacy concerns, participants in the *new users* category frequently reported that proximity was a decisive factor. The closer bystanders were to them, the more concerned the wearers were when taking pictures, while people standing further away were seen as less of a problem. Hence, many participants expressed discomfort using the glasses in both crowded spaces and private spaces such as a friend's room. In contrast, most positive experiences our participants reported took place in secluded spaces such as nature. Among bystanders, wearers showed special concern for children and the elderly. Both groups were perceived as less tech-savvy, making the privacy indicators even less effective.

> "*If there were a lot of people, especially kids, I wouldn't take pictures. I wouldn't take the videos. I'll just maybe wait until it clears up a bit and then start taking videos because I think it's a lot better to have fewer people in the shot than have more.*"[E3]

However, bystanders were not the only reason why our participants experienced privacy concerns while using the glasses. Most participants were aware that recording sensitive information, e.g., credit cards or copyright-protected material, can also have negative security and privacy implications, which they wanted to avoid. In addition, the audio recording capabilities of the glasses opened the door to potential privacy invasion when conversations were recorded. In such cases, the voices picked up by the camera could even be from people outside of its frame. Participants were, in general, positively surprised by the quality of the audio and video recording capabilities of the glasses. However, this also aggravated their concerns.

> "*I think there's definitely the potential for a breach of security if it were someone that was trying to protect their privacy. It's so much more than CCTV as well. CCTV is everywhere, and you can't get away from it, but it's not as intimate as the glasses. It can't pick up exact conversations and exact details. I think the glasses are a step beyond any recording that we've got just now.*"[E3]

Both existing and new users also reported that they would occasionally accidentally record something they did not intend to. This could happen simply by misjudging what was visible in the picture. Unlike smartphones, these glasses lack a screen that could act as a viewfinder. Participants reported that they could only discern what was actually captured when they inspected the captured content within the app. They also recounted occasions where they triggered a recording unintentionally, e.g., the trigger button occasionally activated when moving or adjusting the glasses.

More commonly, however, participants reported having taken a video when they wanted to take a picture, as the length of the button press determines the function. A button 'press' triggered video capture, while a 'press and hold' triggered image capture. In these instances, participants explained that both bystanders and wearers were not sufficiently notified of ongoing recordings by the privacy indicators.

> "*When I was trying to connect to the app to retrieve the picture that I took on purpose. I found this video that was a little bit embarrassing because I didn't know I was recording and even the waiter, even the concerned person wasn't aware of that, knowing that at a certain time we saw each other face to face. Normally there is that light bulb or that light signal that gets enabled whenever you're recording. I think that because it was too sunny, it wasn't showing.*"[E2]

Regarding concerns about privacy, most participants perceived themselves as engaging in responsible behavior. Still, they predicted that the majority of pictures taken with camera glasses would eventually be shared online. At this point, a potentially large audience would have access to the images, which is where our participants drew the line for privacy concerns. N2 reported: "*I think the problem arises when you upload the photos. When that goes online, that is where it becomes an issue.*"[N2] In addition, privacy concerns associated with camera glasses extended beyond exposure towards other people to include suspicion towards the companies providing them.

> "*The most concerning part of it would be regarding how Meta as a company processes the data itself, because you can control the part where you have control, especially recording, etc. Most of the time a lot of information in probably the whole pictures and videos that you take are being sent to Meta servers to process them. That may be a little bit problematic in*

> *terms of privacy. I know that they are working a lot on those matters, especially regarding privacy and security. As we know, you cannot guarantee privacy or security 100 percent of the time.* "[E3]

5.2.2 Concerns about Bystanders' Attitude. Our participants reported on a wide range of attitudes they experienced from bystanders while wearing the glasses. Some encountered positive feelings such as curiosity: "*I don't think there was even one instance where I felt like people were judging me, but I think they were more amazed and excited to know more about it.*"[E6] or excitement: "*My close friends and family, they knew I got [the glasses] and I'm able to record. I even showed it to them, demo the different functionalities, etc., and they were all amazed.*"[E2]. Others reported that bystanders would often be indifferent: "*I don't think anybody cared, really.*"[N2] or questioning about the glasses "*[Bystanders] probably at first would be like, 'Are these sunglasses? What are these?'*"[N2] The majority of our participants, however, were concerned about bystanders' negative attitudes. Particularly, participants feared that privacy-sensitive bystanders could react in a bad way if they were in the presence of a camera. N5 explained: "*One reason I didn't want to use it with strangers was that you don't know who is a [sensitive person] and if they get hostile towards you.*"[N5] Regarding friends as bystanders, wearers reported feeling a sense of betrayal. Some participants felt deceitful for not informing their acquaintances about the glasses, which they only learned about later, despite the fact that the participants did not record anything. This feeling was again reinforced by the perceived deficiency of the technology when it comes to informing bystanders.

Most of our participants generally articulated that they wished to avoid unwanted attention from bystanders. It is important to note that this perception did not arise due to wearers actually invading other people's privacy. However, given the impression our participants had about bystanders being unable to tell when a recording was happening, the wearers felt constantly suspected of misbehaving.

> "*I was a bit afraid that people would approach me and say they didn't want to be recorded or something, even though I hadn't pressed the camera. Or I wouldn't have wanted to explain that to anyone, because I hadn't really done anything bad at that moment. I really wanted to avoid listening to unnecessary accusations like that or something.* "[N3]

5.2.3 Bystanders need to Trust Wearers. In summary, wearers were under the impression that the current technology did not sufficiently aid them in non-verbally communicating with bystanders about potential privacy invasions. In addition, our participants concluded that the privacy indicators could easily be manipulated or disabled by malicious users. Furthermore, they experienced accidental recordings, which could violate other people's privacy even with benign use. Consequently, our participants reported that the only thing left to do for bystanders, who naturally want to protect themselves, is to trust in the righteousness of the wearers. Coupled with a potential loss of control that occurs when captured content ends up online, this reliance on trust increases the burden on the users of camera glasses, who feel like they are the only line of defense for other people's privacy. The feeling is reinforced when the wearers are under the impression that not many people even know about the technology at hand. While our participants can see many benefits of using camera glasses, the intrinsic social pressure they experience can outweigh the positive emotion.

> "*There's a light that goes on, but in order to fulfill the function of the light - that people know what's being filmed now - people have to know what the light means. And if there's a transitional phase where these glasses are not yet widespread, but people are already using them, then it's very easy to film people without their consent or their knowledge. Which then again gave me a bit of a strange feeling because I don't want to be filmed without my knowledge. But I also don't want to make others feel like they can't trust me when I'm wearing these glasses. [...] Because even if people know, you can't always ask everyone for permission when you're walking around town or lying around by the river.* "[N5]

5.3 Wearers' Mitigation Strategies

Wearers felt they were responsible for preserving the privacy of bystanders when using camera glasses. Since the technology did not provide them with sufficient tools to lift this burden off of their shoulders, our participants reported that they developed their own mitigation strategies. These were, for the most part, non-technical solutions that users could easily implement.

Record under non-sensitive circumstances only. Our participants stated that to minimize potential privacy issues, they would primarily use the glasses for recording non-sensitive occasions, such as pictures of nature. Most participants explained they would primarily use the glasses in public places, while avoiding recording in private spaces. Also, they would resort to taking pictures when fewer people were around or wait till people in the camera's frame would wander off or at least turn away, such that no faces are visible in the photo. Similarly, participants would avoid staring at bystanders directly while wearing the glasses.

> "*I would not put them, e.g., on a company event or so, nor use them in situations where the data recorded or the conversation that I have may be a little bit sensible. Besides that, if I am in a public environment, I would definitely use them without any issue.* "[E2]

Not wearing the glasses. Participants also talked about circumstances where they would simply refrain from wearing the glasses due to privacy concerns. Often, this was the case when wearers were concerned about the bystanders' attitude. Our participants stated that they wanted to avoid drawing attention to them in general, which was especially true for adverse reactions. Hence, in circumstances where the bystanders' sentiment could not easily be assessed, they refrained from using the glasses.

> "*I wouldn't have worn it on the train because I didn't want people to think that I was filming them or something. That's why I just left it in my pocket, even*

though I would have had the opportunity to listen to music on the train. "[N4]

Wearers also demonstrated their mindset around using the cameras. It was strongly connected to a desire to record and share memories and experiences. When they did not expect such a situation to occur, they would often not use those glasses at all to avoid running into privacy issues.

> "*Most of the time when I wear the glasses when I wanted to share things. In my mind, I had the motivation that I'm wearing these glasses because the next moment I'm going to share on Instagram. If there is something which I don't want to share, I never wear the glasses. There was this kind of a privacy scale in my head all the time that if it's a private moment, I am not going to wear the glasses.* "[E5]

Some participants described how they would turn off the glasses, using the physical kill switch, when they found themselves in privacy-sensitive circumstances. A strong motivation for this practice was accidental recordings, where the recording would get triggered without the user's intention. However, since bystanders could not determine whether the glasses were turned on or off from the outside, participants often still felt uncomfortable.

Explain glasses to bystanders. When participants wanted to use the glasses around other people, they would go on and explain the technology behind the glasses to bystanders. This was mostly the case with friends or close acquaintances. By explaining how the glasses work, the wearers could tackle the problem of missing awareness on the bystanders' side. Afterwards, the burden of respecting everyone's privacy was shared since bystanders could now take adequate actions when they felt their privacy might be invaded. However, this practice did not scale well and was therefore less feasible when participants wanted to use the glasses in a crowded environment.

> "*I did explain [how the glasses work]. I said, okay, I'm not looking at you right now, or even if I'm looking at you right now with the camera, nothing happens, because I only take a picture here when I press on it, and then you also hear that. And I don't make videos of you then either. And that's why it felt better then. You first have to explain how it works.* "[N4]

On occasions, participants explained the glasses to strangers. Also, people would approach them directly after being recorded or at least have the suspicion thereof. In these cases, our participants stated they most often went for a full-disclosure approach to resolve the situation. They would try their best to explain how bystanders can notice whether a recording was happening and also show them the pictures in the app in an attempt to demonstrate their benign intentions. If indeed there existed a recording of a person who expressed their dissent about it, wearers honored the bystander's request for deletion. Similarly, participants disclosed that they would remove the glasses if any bystanders directly complained about them.

> "*If someone were to approach me, I would then also try to explain this to them. I could also show them directly in the app that I didn't take pictures of them.* "[N4]

However, most participants stated that it was difficult to resolve all such privacy-sensitive situations with complete certainty, meaning that bystanders would always need to rely on trust in the wearer's good faith.

5.4 Wearers' Feelings

Participants disclosed to us how they felt when using camera glasses. Most of them talked about negative emotions such as embarrassment and discomfort. These feelings arose in situations where wearers worried about being suspected of illegal or unethical activities (e.g., stealthy recording) by bystanders. In such cases, participants were also concerned about bystanders reacting negatively to them using camera glasses.

> "*I definitely felt uncomfortable if people were around and I didn't want to do anything to make people uncomfortable or look sneaky, like I'm doing something sneaky.* "[N2]

Participants experienced positive emotions when bystanders reacted with curiosity or excitement after learning about the technology.

> "*Most of the people who noticed that I'm wearing glasses with a camera, they had a negative feeling towards it, which makes my feeling negative as well towards the glasses. There are few cases when people are super excited about it and ask me questions, then I felt good.* "[E5]

Some participants stated that they felt indifferent in certain situations. This situation mainly occurred when participants assumed that bystanders were not attentive or did not care about them, as it was a public setting where people may anticipate being observed to some extent. A few participants also reported being more sensitive towards other people and their privacy concerns while wearing the glasses. However, we suspect this might be partially influenced by the fact that they had to keep a daily diary and answer questions about how they think other people perceive them.

Finally, a familiar sensation among our participants was feeling like a spy when using the glasses. They associated them with gadgets used in pop culture movies. Due to the perceived secrecy of the cameras, participants described feeling devious, as if they would deceive the bystanders. N2 explained: "*Maybe it is also combined with the outfit I wear. I completely feel like if I put glasses on like a full black spy-looking outfit, then it would be a little bit scary maybe to people.*"[N2]

5.5 Wearers' Needs

5.5.1 Build Awareness. Our participants identified a lack of awareness of the technology as a major factor when it comes to the wearers bearing all of the burden in terms of preserving other people's privacy. Currently, the only strategy wearers could apply to address this inadequacy was explaining verbally how the technology works, especially the privacy indicators. This would require significant effort, particularly when our participants wanted to use the glasses in more crowded environments. Hence, they expressed a need for additional awareness-building tools. These tools could

come in different shapes and increase both long- and short-term awareness (i.e., immediate awareness of recording).

More effective privacy indicators. In terms of technical solutions, most participants agreed that the LED indicator needed to be improved. In its current form, participants described it as too small, too inconspicuous, too faint for sunny conditions, and that the color lacked the correct signaling properties. Participants expected the color red to be better associated with video recording. Another request was the inclusion of side-mounted LED indicators. That way, bystanders could already notice a recording in progress before walking into the frame of the camera.

> "*They can make the LED a little bit more like flash looking, more attention-grabbing and more obvious.*"[N2]

Some participants also suggested a continuous visual indicator, i.e., a permanently shining light when the glasses were on. This indicator could then change color depending on the type of recording.

> "*Only if it somehow lights up permanently, then I think that would even more so... If you say white means it's normal and green means it's taking a picture or something.*"[N4]

Besides the LED, participants believed the audio feedback (sound replayed when triggering a recording) could be used as a privacy indicator. However, the current solution was deemed insufficient. They requested more conspicuous notifications, which should also more explicitly notify anyone nearby. Some wished to include vibrations along the visual and auditory feedback. This would mainly serve to inform the wearer and could, therefore, reduce accidental recording.

> "*Theoretically, you could just adopt that from Japan, that the glasses have to make this noise when the camera is used. [...] I would like that. Then you also know that it worked because you actually have to grope blindly for the button. And sometimes, it's not quite clear. Did it start filming now or not? And if there's a loud audible click at the beginning, then I know it worked, and I give my fellow people the opportunity to turn to me and see what I'm doing.*"[N5]

Educating the general public. Our participants stated that the problem should not be addressed with technical solutions alone. Non-technical solutions proposed included more extensive advertisement of the glasses and a broad public discussion about the technology. Furthermore, some participants called on the media to educate the general public about camera glasses and how to detect them. Some talked about how comparable technologies, such as Google Glasses, were much more widely known due to comprehensive coverage. Once the general public was sufficiently informed about camera glasses, our participants expected the technology to slowly weave into everyday life. One could also interpret this as a convenient way of shifting part of the privacy burden to the bystander.

> "*I think people would get used to it relatively quickly, especially when it's then in the media and explained by the daily news and Instagram. Then, I think it will be normalized relatively quickly.*"[N5]

Distinct design. The design of the camera glasses could aid wearers in communicating with bystanders and improve awareness. Our participants stated that a distinct design clearly identifying the glasses as camera glasses would be beneficial from a privacy-preserving point of view. The current design is very close to regular sunglasses, in sharp contrast to previously available smart glasses, which often feature a distinct, futuristic look or clearly marked cameras (e.g., Snap Spectacles). Our participants felt the current design makes it almost impossible for bystanders to identify the camera glasses even at short distances. E5 explained how design can aid in communicating the very essence of a device: "*If you see a sports car, you know that this is a sports car because it has its distinct design. If these are special built camera glasses, then they should have a design [...] which says that all the camera glasses should have this shape, and then if any company makes camera glasses, they should look like it.*"[E5]

5.5.2 Control Over Data. Finally, our participants also requested better means of controlling their own data (i.e., their camera recordings). Since they felt mostly in charge of protecting other people's privacy, the wearers wanted to have extensive control over all aspects of recording, processing, and storing pictures and videos. In this context, participants expressed their dislike of the company developing the glasses (i.e., Meta) and how tightly the glasses are coupled to the company's ecosystem. In order to use the glasses, people must first sign in with a Meta account. E2 stated they wanted future technology to be "*not 100 percent connected with Facebook or with Meta. Have 100 percent local control on the glasses.*"[E2] The connection to a social media ecosystem also negatively impacted transparency for the wearers. Some were unsure about where their data is processed and which information is shared with Meta.

In order to take back control, some participants wished for non-technical solutions. Currently, the glasses possess a kill switch that turns off the power supply. But it is located on the inside of the frame, which makes it impossible for bystanders to see whether the camera is active or not. Even wearers themselves were sometimes uncertain about whether their glasses were on or off. A proposed alternative was a physical cover that would be attached to the glasses to cover the lenses, much like what is often used to cover built-in webcams in laptops and smartphones. This physical closure could help provide a low-tech solution that is easy to understand for both bystanders and wearers alike.

> "*It would be quite practical if it somehow had a flap that only opens when you take a picture. Or you can somehow temporarily put a clip on it when you know that you're just taking a train and not taking any pictures.*"[N4]

Other participants proposed software-based solutions. These include a pop-up in the app informing wearers about potential privacy violations when downloading pictures from their glasses. The system could also automatically blur bystanders' faces in an effort to preserve their privacy, as proposed by N2: "*it should have an AI built in it to blur the faces, like Google Maps does.*"[N2]

5.6 Wearers' Ethical Considerations

When considering potential ethical issues around camera glasses, participants often compared them to existing technologies, mostly cameras, smartphones, and CCTV. Most wearers felt the same ethical guidelines apply, meaning that simply owning and using the technology for benign reasons was ethically acceptable. They drew the line when it came to exploiting the technology for malicious intentions, such as deliberate concealed recording.

> "*Just wearing the glasses is fine to me. Recording it without the consent of everyone who is there in the room, some of them whom I don't even know, and they're doing their own thing, and if I start recording them, it's wrong. It's like if you're in a private ceremony and you suddenly take your phone up and start recording everything. It violates the privacy of everyone in the room.*"[E5]

Participants talked a lot about the importance of consent. However, they noted that consent can only be given if bystanders have knowledge of the technology. Also, obtaining consent could be challenging in public spaces due to the high number and constant movement of people. In contrast, obtaining consent from even a few people would require the wearers to repeatedly describe how their glasses work in detail.

> "*I wore them at the university. I told my fellow students around me what these glasses could do. So they know that they could be filmed or photographed. But when I wear them in the summer at the lake or walk down the street, there are hundreds of strangers. I can't go up to everyone and tell them and ask if it's okay.*"[N5]

Some participants found it easier to ask for consent after they had made a recording. However, most wearers acknowledged that in such cases, it might prove challenging to negotiate the recording's whereabouts in the case of a rejected consent. As in so many cases above, the bystander is condemned to trust that their request for deletion is honored. E2 explains: "*you can tell him I'm going to delete it, but he has no proof that you will be deleting it unless he simply breaks [your glasses].*"[E2]

5.7 Putting Themselves in the Bystanders' Shoes

Throughout our study, we often found that participants would switch perspectives and put themselves in the bystanders' shoes. Examples mentioned above include the reflection on the effectiveness of the privacy indicators or whether the usage of camera glasses was ethically justifiable for a given situation. In particular, the participants reflected on how they would feel in a similar situation as a bystander. E2 stated: "*It was a little bit disturbing to be completely honest with you, because I told myself, I may be in his place and someone may be recording me without me knowing or noticing*"[E2]. This demonstrates an overall empathy of wearers towards the bystanders, especially their privacy needs and feelings.

6 DISCUSSION

6.1 Comparing New and Existing Camera Glass Users

We recruited two groups of participants for our study, one with and one without prior experience with smart glasses. These two groups showed subtle distinctions in their privacy perspectives. While our qualitative data is not suitable to draw direct comparisons between populations, and considering the confounding demographic factors (e.g., age and gender) between the groups, we discuss potential differences based on our observations.

Our analysis found that new users reflected critically on the camera glasses, while existing users did not apply the same scrutiny. During our 14-day diary study, we observed that new users' privacy concerns diminished over time, indicating an acclimatization process. Existing users were more content with the glasses' status quo because they had likely already undergone this progression. Hence, new users' concerns could come closer to and eventually converge with existing users' concerns. However, our data from existing users might suffer from survivorship bias, i.e., users with significant privacy concerns likely abandoned their camera glasses before becoming long-term users.

In contrast to the new users in our study, none of the existing users feared legal consequences for their actions. One explanation might be that all new users in our study resided in Germany, which was not the case for our sample of existing users. People living in Germany are heavily privacy-focused [53]. They are also subject to the European Union's GDPR, currently one of the strongest privacy legislation [5]. Germany's privacy consciousness is well-documented in prior work. For example, the acceptance of recording faces is lowest in Germany when compared to the U.S., UK, and China [34].

6.2 Comparing Bystanders' and Wearers' Demands for Privacy

Camera glasses make bystanders uncomfortable and irritated [17, 36]. Our findings suggest that individuals who wear camera glasses feel a comparable discomfort. Wearers empathize with bystanders. They acknowledge that, because of ineffective privacy indicators, bystanders must trust the person wearing the glasses. Past research has shown that bystanders also considered the deployed privacy indicators insufficient [33, 45]. Both wearers and bystanders criticize the weak noticeability and the widespread lack of understanding.

In this ongoing struggle, both parties make implicit assumptions about who is responsible for preserving privacy. Wearers sense that the burden of preserving bystanders' privacy relies on them, along with a stigma of wearing such a gadget, while bystanders despise the loss of control and the need to trust strangers [10, 14]. Hence, we see a need for better privacy mediating technology that does not solely rely on trust.

6.3 Exploring the Design Space of Camera Glasses

We identified areas of tension that need to be addressed in future generations of camera glasses. On the one hand, our results show that wearers want conspicuous privacy indicators to communicate

an ongoing recording clearly to bystanders. They also desired easy-to-identify designs to avoid the feeling of tricking people by using camera glasses in a sneaky, spy-like fashion. On the other hand, wearers also wanted privacy indicators that were less conspicuous to avoid attracting attention. Since bystanders could have mixed opinions on potential surveillance, noticing a camera on another person could lead to negative repercussions. When considering the previously available camera glasses, we see that their form factor was divisive among users and bystanders. Initially, these items were easily recognizable as recording devices, which was not well-acclaimed either [15, 33]. Therefore, this area of tension cannot be solved through design alone. Since the stigma associated with cameras as a surveillance tool is hard to come by, future research should explore how this predicament can be addressed.

Wearers understand that consent is vital when recording other people and that it is, first and foremost, their responsibility to obtain it. However, as our results highlight, it is often tedious or infeasible to gather consent in crowded places or dynamic environments where people might only have a few seconds to communicate. Since consent requires knowledge of what is happening, extensive explanations about camera glasses might be necessary. Technical details such as what is being recorded and where data is stored and processed are crucial. The technology should, therefore, aid wearers in seeking consent by providing easy-to-understand information. We recommend using familiar designs for form factors, interactions, and privacy indicators, as these can inform the bystanders of an ongoing recording. Post-hoc processing techniques such as detecting and blurring bystanders' faces and other sensitive information can further relieve some of the trust issues between bystanders and wearers [13, 23, 58].

Some prior work sought a broader solution to camera devices at large by shifting more responsibility to the bystanders. There, the bystander would have the opportunity to implicitly give or refuse consent by proactive means with fine-grained situational filters or re-actively on a case-by-case basis. The former could be implemented with smart clothing and visual markers [12, 29, 36] and broadcasting or jamming devices [4, 9]. The latter could be covered by active methods, such as employing a privacy watchdog [25]. Such a tool notifies bystanders whenever a picture is taken in their vicinity. Alternatively, the camera glasses could broadcast a notification to nearby devices after each capture [22]. In either case, bystanders can then decide whether they want to object, thus allowing them to regain (some) control over their depiction. Future work may look into consent-negotiating techniques to minimize the wearers' and bystanders' burden.

6.4 Adoption Obstacles

For recreational recording devices, such as consumer camera glasses, it might prove a major roadblock to the adoption if (potential) customers experience or expect unease when operating them. Therefore, the vendors have an incentive to lessen the wearers' privacy burden to increase revenue. Eventually, privacy is set to become a key priority for the personal recording device industry.

Action cameras like the GoPro, or augmented reality devices such as the Google Glass have a distinct design, which makes them easily recognizable. In fact, they became so iconic that the International Organization for Standardization (ISO) chose them for the hazard and safety signs of that device class in ISO 7010 [19]. Camera glasses are still a niche product. Up until now, these gadgets have mostly appeared in fictional spy movies [20]. Therefore, most people are not aware that such a technology exists or at least do not actively look for signs of it in their daily lives. Vendors can address this lack of knowledge through extensive marketing campaigns and sensitize resellers (opticians, etc.) towards privacy aspects. This can lead to a mutually beneficial outcome as we expect such measures to impact sales positively. Increased knowledge in the general public can benefit the wearers' experience: It helps lift the burden and defuse tension in privacy-sensitive situations, thereby promoting the adoption of this technology further.

7 LIMITATIONS

Our diary study, like many self-reported studies, has certain limitations. Self-reported diary studies can be subject to over-reporting and over-observation [27, 42, 43]. To lessen this effect, we gave participants the freedom to report in a way that suits them best. This helped prevent any unintentional influence on their responses.

Studies that rely on self-reported data can be biased due to participants trying to present themselves in a socially desirable way [18, 55]. This is particularly true for studies that prioritize privacy. To minimize social-desirability bias, we took steps to avoid influencing participants during recruitment and reassured them that we wouldn't view or save any photos or videos they took during the study. This allowed participants to speak candidly about their privacy experiences during the exit interview.

Our recruitment strategy involved utilizing online forums and distributing flyers throughout the city. We believe that our participants were motivated by their interest in innovative technology and this drove their desire to participate in our research.

All of our new users were residents of Germany, which could introduce a geographical bias and affect the privacy concerns raised in the study. We discuss the potential impact of this geographical bias on our results in Section 6.1. We recommend that future work consider different demographics, especially privacy concerns of understudied populations. Furthermore, the limited sample size provides constraints to the applicability to the general population and different cultures. However, we recruited a balanced gender spread from four countries to improve diversity.

At the start of the study, the Ray-Ban Stories camera glasses were only available with tinted lenses for use as sunglasses. However, Ray-Ban has recently launched another version that comes with clear lenses. As such, our participants reported wearing them primarily in sunny conditions and while outdoors. Indoor settings may have a more intimate atmosphere thereby affecting the usefulness of privacy indicators. We recommend for future work to replicate our study with clear lens glasses, when they become available.

8 CONCLUSION

Cameras are increasingly being incorporated into everyday items. The Ray-Ban Stories are the latest addition to the landscape of camera glasses. They offer photo and video capabilities, are fashionable and virtually indistinguishable from non-smart sunglasses.

This comes with privacy implications when people use the glasses around bystanders or record potentially sensitive information.

In our study, we investigated the wearers' perspectives on such privacy challenges and how they tackle them. We covered both experienced and first-time users.

Our findings indicate that wearers are empathetic to bystanders' privacy issues around camera glasses. They feel the emotional burden of preserving everyone's privacy. Wearers complained that currently available technology does not assist them efficiently to reduce this burden. The built-in privacy indicators are not effective in notifying bystanders. Neither the design language of glasses and their privacy indicators, nor the technical implementation (e.g., faint LED) convey the message effectively and unequivocally in everyday situations. The situation is further amplified by the stealthiness and novelty of this device class and the resulting low familiarity among the general population.

We also discuss the relationship between the perspective of the wearers and that of bystanders. We propose that consent negotiation and fine-tuning the visibility of privacy indicators are crucial challenges that need to be addressed in future work to ensure camera glasses can be used in a privacy-preserving way.

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A APPENDIX

Part	Question, Explanation	Comments
1. Introduction & Oral Consent	Thank you for your participation in our diary study. This is a follow-up interview to the diary study where we will be asking you questions in relation to your diary entries. Before we proceed, please remember that there are no right or wrong answers and you can say anything that comes to your mind. Are you ok to continue? Do you consent to recording this interview?	
2. Warm Up Questions	*Existing Users:* Since when do you own the glasses? Why did you buy the glasses?	
	New Users: Tell me about your experiences in the past two weeks. What are some use-cases where you see benefits of these glasses?	
3. Questions based on Diary Entries		Ask about interesting entries from diary and discuss them
4. Questions if Topic did not come up	How did you feel when you first wore the glasses? *Follow-up:* Did you feel any sort of awkwardness? Was there any instance when someone noticed you while you're recording something? Did you think about covering up the light just to make sure that it looks even more like a normal sunglass? *Follow-up:* Why/Why not? Did you ever feel that you were breaking into someone's privacy? Did you at any point want to stop using glasses? Did wearing the camera glass change your privacy behaviour?	Only used if participants themselves don't bring up these topics
5. Needs	What are your needs with respect to the glasses?	Ask about specific privacy needs, if not brought up
6. Outro & Debreifing	Do you have any questions, or comments? Would you like to add anything else? Thank you for participating in this interview and diary study. If you have any questions in the future, please feel free to contact me.	

Table 2: Interview guideline used for the semi-structured exit interview.

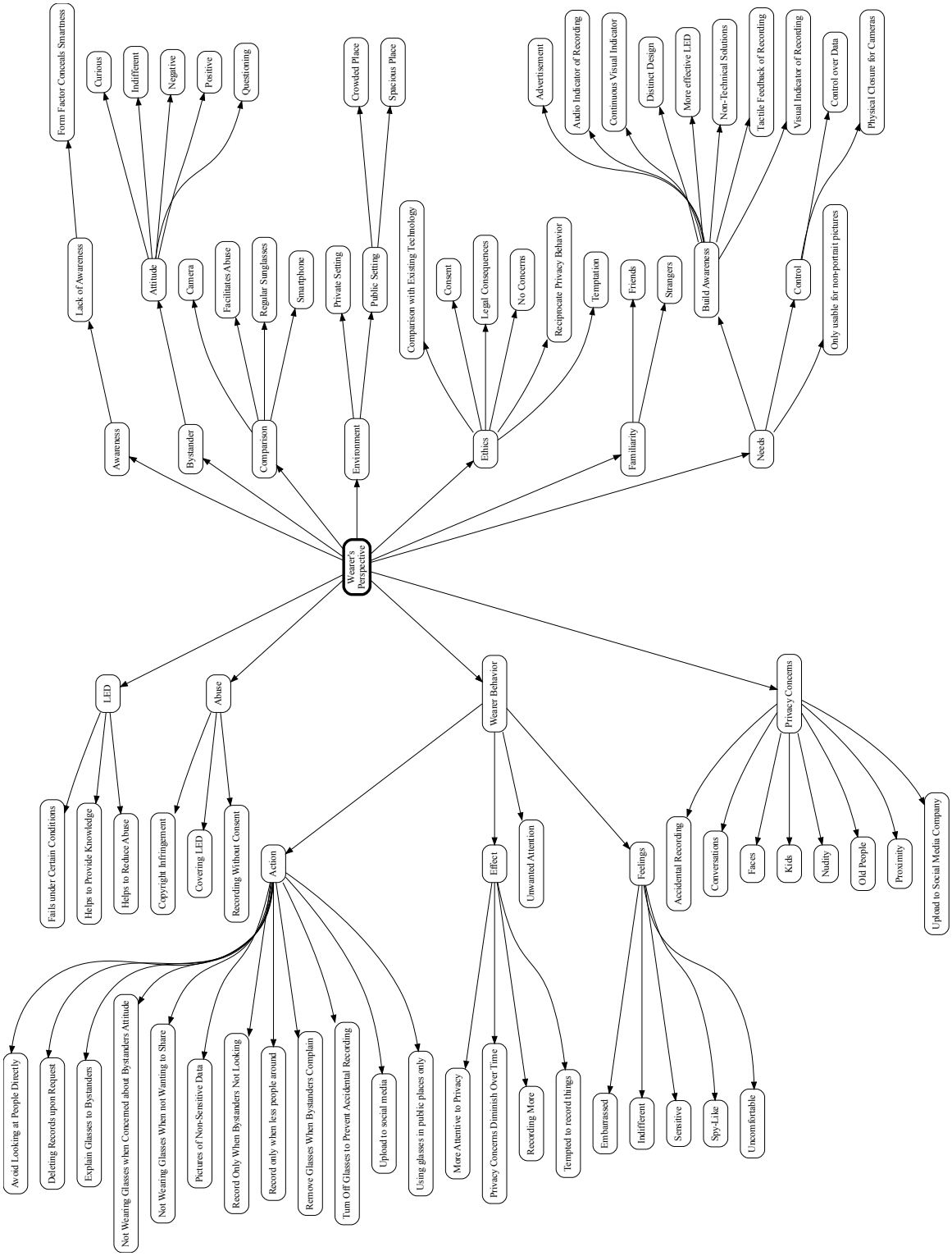

Figure 8: Codebook