Don't look at me like that—How AR face recognition changes our social behaviour.

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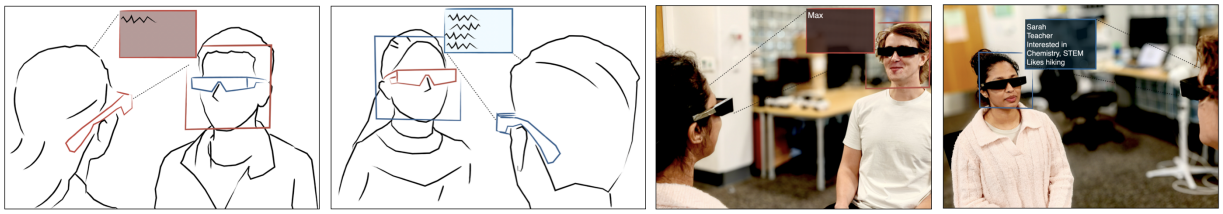

Figure 1: Pervasive AR delivering face recognition-based information introduces asymmetry into everyday interactions. Left: A conceptual illustration of the experience. Right: The study setup as experienced by participants.

Abstract

Pervasive Augmented Reality, as a context-aware and ubiquitous technology, captures and scans a user's environment to create and tailor augmentations for the user. We assume that Pervasive AR will not only be commonplace in recognising the general environment of a user but also include the identification of people in its context by way of face recognition. While there is a body of research addressing privacy issues with Pervasive AR technology and face recognition individually, less is known about the implications of the asymmetry of information availability and agency on users' perceptions, acceptability, and ethical concerns. In addition, little is known about potential social behaviour changes due to those aspects. We exposed 50 participants to a purpose-developed Pervasive AR technology probe and explored the ethical and social implications of the experience. Our findings show that Pervasive AR, in combination with face recognition and asymmetric information delivery, can lead to skewed social interactions with consequences that affect users' sense of control, agency, and identity. Furthermore, this exploration raises questions about technology acceptability in general when bringing together emerging technologies, like AR and face recognition, as queried here.

Index Terms: Pervasive Augmented Reality, Ethics, Technology Probe, Empirical Study

1 Introduction

More recently, Augmented Reality (AR) has been steadily moving away from being solely a display technology [3, 59] and transitioning into an omnipresent everyday wearable technology [16, 49, 51]. This technology will likely become context-aware and pervasive, thus, Pervasive Augmented Reality. Pervasive AR is defined as continuous AR interfaces that seamlessly blend into our environment, delivered via devices that resemble regular glasses [22]. Context-aware Pervasive AR [22] provides a surreptitious medium to deliver tailored information to its users. Pervasive AR systems will take cues from their always-on sensors to create a context for each user at any given moment, taking into consideration the user's surroundings, locations, objects, and bystanders [61].

In scraping information about bystanders, we assume Pervasive AR will tailor and deliver this information to suit the user's needs. Real-time face recognition via AR has promising applications in specific contexts, such as in assisting prosopagnostics [63], emotion analysis for neurodivergent users [5, 37], recognition for visually impaired persons [35, 68], and even social applications such as simply reminding a person of who they are talking to at any given time [52]. While live face recognition will offer new ways of connecting with others, it will have social implications, especially if the information about another is tailored to a user's requirements, creating an asymmetrical information flow between users.

With AR becoming an omnipresent and everyday technology, the potential social and ethical repercussions have become more prevalent. While there exists a vast body of work exploring the ramifications of Pervasive AR and face recognition technology (FRT) separately, the multifaceted combination of the two technologies is yet to be investigated. Currently, people can use any of the plethora of systems[1] readily available to do a face-based search on anyone. The primary difference between conducting a search manually using available systems and using Pervasive AR-based face recognition is that, in the latter, the system performs the search on behalf of the user.

Research projects have conceptualised the use of FRT with Pervasive AR [66, 67]. However, these works have not explored its effect when FRT-based information is tailored to each user as Pervasive AR systems would do with all augmentations it deliver to its specific user, creating an asymmetry in the information each user sees about any given person. Furthermore, work such as Project Aria [17] exacerbates the need to thoroughly investigate the ethical and socially responsible implementation of pervasive facial surveillance [2]. This gap necessitates a deeper understanding of users' perception of pervasive face recognition and its implications on social and behavioural patterns. In this study, we partnered participants in pairs to experience FRT-enabled Pervasive AR. We present our findings on how users perceive asymmetrical FRT-based information exchange, addressing the following research questions qualitatively.

RQ1: How does the symmetry of tailored information delivery affect users' first impressions of others? Our research suggests that first impressions are formed within the first minute of meeting someone [4]; therefore, we assume that the information

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[1] e.g.: www.pimeyes.com/, www.socialcatfish.com/

the glasses reveal to a user about another person, and how much that person sees about the user in return, will factor into the impression formation process. **RQ2: How does the symmetry of tailored information delivery in social interactions affect users' perceived control?** We assume that the user with more information about their partner during an interaction will have more perceived control over that conversation, owing to the fact that they know more about the other person. **RQ2.1: How does the user's perceived sense of control affect the social acceptability of Pervasive AR?** We assume that Pervasive AR would be deemed more socially acceptable when the user's perceived control during an interaction is high.

Our main focus is on, **RQ3: How is the delivery of tailored information about others via Pervasive AR ethically judged?** We assumed the scepticism of the use of facial recognition in public spaces would extend to Pervasive AR, even though, in this case, the participant himself receives the information. **RQ3.1: How is the delivery of tailored personal information in social interactions judged when the amount of information accessed and shared is symmetric?** With this question, we explore the need for information equality when receiving information about others in the environment. **RQ3.2: How is the asymmetric delivery of tailored personal information judged when users are made aware of the existing asymmetry?** Although we believe that the information delivery via Pervasive AR will often be asymmetric, we explore whether being informed about when a user is receiving asymmetric information will alleviate users' concerns.

We conducted a 50-participant qualitative user study to address the above research questions. Each participant experienced a near-real simulation of pervasive facial recognition. The findings from our work aim to inform the design of ethically responsible Pervasive AR systems and real-time facial recognition applications. Furthermore, this research contributes to the ongoing dialogue about formulating public policies and frameworks to protect the users of ubiquitous technologies such as this.

2 Related Work

Pervasive AR technology is ubiquitous and context-aware [21]. It superimposes relevant augmentations to the real-world environment of a user, posing some basic perceptual, acceptability, and ethical questions [50]. With its always-on cameras, it leads us to believe that Face Recognition (FR) will be an organic function of Pervasive AR systems in the future. Here we look into previous and related work in surveillance and sousveillance (recording of activities by members of the public) and existing research into applications of FRT, in particular with wearable devices. Of interest to our research, which combines Pervasive AR technology with FRT, is the presentation of oneself, in particular for first impressions, based on unprompted information, as pointed out by e.g. Perera et al.[45]. Often, people would use an *idealised self-presentation* [20]. Pervasive AR, to a certain degree, takes away the ability to control how others perceive an individual. Pervasive AR influences our sense of control by letting others control how and what they want to learn about an individual via FRT. Therefore, here we also look into work which examines self-presentation in digital contexts.

2.1 Surveillance and Sousveillance

FRTs are currently being used in several security and law enforcement-related applications (see Gravie et al.[19] for American law enforcement), e.g., prevalent in airport security[1], access control in public spaces during COVID-19 [41], and general surveillance like "Skynet"—a Chinese network equipped with over 560 million surveillance cameras[47]. Wassom[66], discussing FRT for AR, claim that due to most regulations or the lack of it, it would be difficult to remain anonymous in public spaces. They argue that the public will not be able to say no to FRT because faces will be categorised as personally identifiable information. Furthermore, they claim that facial privacy would be more effective when delivered by the market than by law enforcement. Similarly, Learned-Miller et al. [34] claim FRT-enabled surveillance could threaten a person's right to anonymity in public, discouraging people from protesting (freedom of speech) or associating with certain people. FRT adoption trends vary from country to country and even state to state, depending on the privacy and data protection legislation in place. Several cities in the United States of America, such as San Francisco and Boston, have banned the use of FRT by government agencies due to privacy and inaccuracy-based concerns [1, 18]. Hasan et al.[23] identify different technical levels of facial privacy that can be implemented with FRT systems. While privacy and data collection are surely of great concern, FRT poses ethical conundrums, too, when used on unassuming bystanders.

2.2 Assistive and Social Applications

Existing studies highlight that Pervasive AR technologies are socially acceptable when they are catering to a specialised need. For example, Perera et al.[45] report that participants favoured Pervasive AR functionalities that would improve their productivity. Kelly and Gilbert [30] state functionalities that would cater to differently-abled persons to be the most acceptable. Similarly, FRT has been explored as a solution for special needs. These applications vary from catering to visually impaired people [35, 68], persons who are unable to recognise others or remember faces [63], and people who find it difficult to interpret emotions [5, 37]. Benssassi et al.[5] review existing assistive applications for neurodivergent users, which are capable of emotion recognition through facial expression analysis. Similarly, Madsen et al.[37] and Washington et al.[65] discuss the development of wearable devices that analyse the emotions of others and give appropriate real-time cues to neurodivergent users to improve their social skills. Another application of FRT that has been explored as an assistive application is in helping prosopagnosia—the inability to recognise and distinguish between faces. Wang et al.[63] discuss the development of an eyewear for prosopagnosics that tells the user the name and the relationship to the person they are seeing in front of them.

Applications of FRT are not limited to assistive applications but also extend to social applications. Worstall[67] highlights the appeal of FRT-enabled applications for AR glasses, which can subtly remind users of names and summarize past meetings. Rhodes[52] discuss an early vision of Pervasive AR, emphasizing the value of context-aware wearable devices for task recall. They stress the importance of using techniques like face recognition to support users in social interactions. Similarly, Utsumi et al.[62] examine the design and implementation of a mobile real-time face recognition system to enhance human memory. Singletary and Starner[55] discuss the use of face recognition systems for improving memory and detecting social interactions while ensuring minimal interruptions from the device. Mandal et al.[38] discuss implementing a system that logs interactions and recalls names. Work by Pentland and Choudhury[44] discuss the different face recognition efforts, applications and shortcomings while also briefly highlighting the importance of face recognition in day-to-day wearables to help users recall names.

We assume pervasive and social FRT would alter our interactions as they deliver unprompted information about those we meet. While it will change how we perceive others and our first impressions, the knowledge that others are already receiving information about us could change how we behave and present ourselves. As the audience now will already know some information that would otherwise be shared in a first meeting. Self-presentation and first impression are concepts that have been explored in sociology, and we assume they would change with pervasive FRT-based information delivery via AR glasses.

2.3 Self-Presentation in Digital Contexts

A considerable body of work investigating self-presentation via social media and avatars already exists (e.g. [20]). Devito et al.[14] discuss different aspects of social media platforms that affect a user's self-presentation. Hollenbaugh[26] notes that users' self-presentation is based on the following aspects: social media affordances, anonymity, persistence, and visibility. Litt[36] identifies that most users consider their *imagined audience* to be the most contacted or commenting peers.

Chung et al.[11] explore the interactions between AR users and non-users, claiming that non-wearers deem the loss of control over their self-presentations when wearers would project augmentations on non-wearers, a critical issue. Kytö and McGookin[33] show how self-curated representations can be useful at all stages of a conversation. With today's technology, we can also incorporate FRT-based reverse-image searching to deliver scraped information about detected users as a more likely scenario for the near future.

As discussed, Pervasive AR is a context-aware system that will deliver timely and relevant information to users. Just as the environment and locations, people around a user make up the user's context. We believe Pervasive AR systems will extend their functions to deliver FRT-based information about those bystanders to the users. While FRT has been extensively explored regarding its legal and rights implications, it is important to investigate the social and ethical impact it will have on users. Especially, focusing on users' ability to accurately present themselves to receive a desired first impression and their perceived control of interactions.

Firstly, we explore the effect the information inequity from tailored Pervasive AR systems will have on the first impressions users construct of others and users' self-presentations. Secondly, we investigate the effect that FRT-based tailored information consumption has on users' sense of control in social contexts. Finally, we look at the social and ethical implications of the above-mentioned aspects of Pervasive AR systems.

3 User Study

This study was designed to explore, 1. how the asymmetry of tailored information affects first impression formation, 2. the effect of information asymmetry on users' perceived sense of control and social acceptability, and 3. how the delivery of information about others via Pervasive AR is ethically judged. The study consisted of three conditions and two variables. The two variables were, 1. symmetry, dictating whether the information exchange between users was symmetric or asymmetric, and 2. awareness, defining whether users were informed of the symmetry of information or not.

The **Symmetry** variable was based on the categories of information that participants disclosed they would prefer to share about themselves, and they would prefer to know about others (during the pre-study survey). We defined these categories based on the different platforms that have been investigated in the virtual self-presentation domain [14, 70]. These platforms are distinguished from more formal platforms (such as LinkedIn)—conveying *General information* and less formal multi-purpose platforms (such as Facebook)—conveying *Social information*. The categories were as follows: 1. *Basic information*—name only, 2. *General information*—occupation, occupational interests, and 3. *Social information*—hobbies, skills, hometown.

This study followed a pair design where a participant was exposed to each study condition (Figure 2) with a new partner, creating a fresh pair for each condition to ensure accurate first impressions. During the pre-study survey the participants picked either, 1. *basic only*, 2. *basic and general*, or 3. *all categories*, for their sharing and seeing preferences separately. The **Symmetry** variable has two levels that are based on the responses from the pre-study survey: 1. *Symmetric*—participants saw at the lower of the two sharing preference levels selected by them and their partner, 2. *Asymmetric*—participants saw categories of information about others that they preferred to see, regardless of how many categories of information they were willing to share with others. This condition was designed to realistically simulate a future pervasive face recognition system that would source information about a detected person via a reverse-image search, and return publicly available information about the detected person, tailored to the Pervasive AR user's preferences. The second variable was **Awareness**, which had two levels: 1. *Aware*—the glasses indicated if the information seen and shared is symmetric and which categories of information about the user were being displayed for others, and, 2. *Unaware*—there were no indications about symmetry or the categories of information seen by others.

Although all levels in the two variables combined make four combinations, we opted to test only three conditions to avoid participant fatigue. We decided to leave out the Symmetric-Unaware condition from testing as we assumed that when the users themselves generate the information (similar to [33]) and their sharing preferences about how they want to be perceived, it is unlikely that symmetry and awareness would make a significant difference. This condition is similar to creating a social media profile for yourself. Furthermore, we assumed that the idealised self-presentation instance is unlikely to occur in a Pervasive AR setting.

3.1 Participants, Study Design and Procedure

This study was conducted with 50 participants (27F, 21M, 2D) following ethics approval[2]. The participants had a mean age of 24.2 and consisted of 46 university students, 3 staff members and 1 scientist. 35 of the participants responded that they had no prior experience with AR, and 15 responded that they had *some* AR experience. About 22 participants were from a technology-related field.

The participants were recruited via flyers and emails from across the campus and town. All participants received a supermarket voucher worth NZ$20 as a token of appreciation for their time. Participants filled in the consent form, pre-study survey, and a demographics questionnaire before the study commenced. Following an introduction to Pervasive AR, each participant was given a pair of Snap Spectacles (2021)[3] and a key card that defined each indicator they would see during the experience (see Appendix A). In this familiarisation session, participants saw a symmetric information display about the researcher without indications. The participants were advised to hold onto their cards throughout the three conditions. The study consisted of three parts, addressing each condition (see Figure 2).

Deliberately making specific pairings for each condition allowed us to ensure that during the two asymmetric sessions, each pairing had one participant who received less information than their partner based on the preferences each participant had previously defined via the pre-study survey. During the study session, participants were seated with their partners for each condition and were tasked with carrying out a 3-4 minute conversation to pick one of them to go to a pub quiz with. After each condition, the participants answered three questionnaires and an interview was conducted at the end of the study.

3.2 Apparatus

Implementation—The Snap Spectacles-based technology probe allowed participants to experience receiving FRT-based information about other users. We opted to use a technology probe because it creates a realistic simulation for participants that allows them to build upon that experience during the interview session to add more insights [28]. The applications were developed using Lens Studio[4].

[2]This study received ethics clearance from the University of Otago Ethics Committee (reference number: 24/087)

[3]www.spectacles.com/new-spectacles/

[4]ar.snap.com/lens-studio

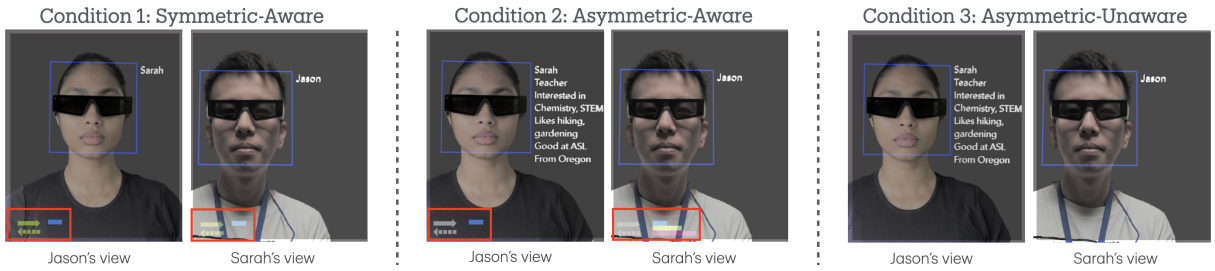

Figure 2: The view of Participant A (Jason) and Participant B (Sarah) as seen through the glasses across the three conditions. Sarah selected to see and share only basic information, and Jason selected to share basic & general information and to see all categories of information. Based on these preferences: Condition 1: *Symmetric-Aware* – Both see at the lower of the two sharing levels selected. Condition 2: *Asymmetric-Aware* – Each user controls how much they see and knows what the other user sees about them. Condition 3: *Asymmetric-Unaware* – Each controls how much they see but does not know what others see about them. Awareness indicators are annotated in red for clarity.

Three versions of this application were developed to represent the three conditions.

The applications did not carry out face recognition, only face detection. Having the pairing determined before the study and participants only interacting with one other participant during each condition allowed us to simulate face recognition using only the Lens Studio face detection capabilities. The information each participant saw about their partner was hard-coded into the three applications prior to each session based on the pre-study survey responses.

Interviews—as our interests were mainly in exploring the ethical implications of tailoring one's personal information to suit another's requirements, the guiding questions for the semi-structured interview were adapted from Stahl et al.[57]'s guiding questions. These served more as a framework to guide the participants. We explored the general themes of receiving information about others and how it differs from looking someone up, participants' thoughts on having others' personal information tailored to the participant's preferences, its effect on self-presentation, first impressions and sense of control in interactions and the ethical implications.

Questionnaires—all participants filled out four questionnaires. Questionnaires 2, 3, and 4 listed below were answered following each condition. 1. *Pre-Study survey*—participants answered this questionnaire before attending the study to submit their information sharing and receiving preferences as well as information about themselves, such as their background and professional interests. This information was used to develop the face recognition applications for each participant. 2. *Perceived Trustworthiness* [27]—this questionnaire had one question answered on three semantic differential scales. Qin et al.[48] state that trustworthiness has a halo effect on first impressions. Hence, we used this questionnaire to evaluate first impressions. 3. *Perceived Control* [25]—this questionnaire focused on participants' perceived control of the interaction they had during the condition and consisted of two questions answered on a 1-7 Likert-like scale. 4. *WEAR Scale* [29]—this questionnaire evaluated the social acceptability of Pervasive AR in the particular experienced scenario. The questionnaire had 14 questions answered on a 1-6 Likert-like scale.

3.3 Data Collection and Analysis

The main data for this study was collected from interviews. We further collected secondary data from questionnaires. The interviews were recorded on an iPhone (14 Pro), transcribed and pseudonymised using otter.ai. The primary author verified the transcripts for clarity against the original recordings. We followed the inductive thematic analysis process prescribed by Thomas[60]. While the main procedure followed was by Thomas[60], we referred to Braun and Clarke[9], and Clarke and Braun[12] for further clarifications when needed.

We conducted the thematic analysis with the following steps: 1. The primary author read and re-read the transcripts in their entirety for familiarisation. 2. The primary author then generated and documented the initial set of codes. 3. A second author independently generated a list of codes by studying a set of transcripts. 4. Following this, both the initial code set and the code set from the parallel coding were compared and combined to create a comprehensive list of codes. 5. The collated set of codes was further refined through multiple iterations. 6. A third author was then given a set of samples of raw text, codes and code descriptions along with example extracts and was asked to assign the appropriate codes to the raw text samples. 7. The results of the third coder's assignments were compared to the list of codes from step 5 and further refined. 8. Themes were developed and discussed iteratively among authors for clarity and validity. Furthermore, we have chosen not to quantify our qualitative findings when reporting to avoid unjustifiable generalisations by the readers, as the interviews were semi-structured group discussions [39].

The questionnaire data was analysed as prescribed in the work from which they were adapted. We calculated the Cronbach's Alpha values to evaluate the internal validity of the questionnaires. Additionally, following the normality tests, Cohen's d-effect sizes and paired t-tests, Wilcoxon signed rankings, or ANOVA were calculated. Furthermore, in data entry, it was revealed that some of the responses had missing values, and those responses were removed entirely from the dataset. Thereby, the Perceived Trustworthiness questionnaire had no missing values and had 50 responses, the Perceived Control questionnaire had 48 complete responses, and the WEAR scale had 49 complete responses.

4 Results

Although three different questionnaires were administered during the study, we were unable to identify any statistically significant differences in our analysis (see Appendix B). The internal reliabilities across conditions of both the Perceived Trustworthiness questionnaire and the Perceived Control questionnaire ranged between poor and questionable. However, the questionnaires served as probes to help participants adopt the appropriate mindset for the interview. Thus, in this section, we report the results of the thematic analysis of the interviews conducted during the study.

We analysed the interview transcripts to develop themes that inform our research questions. Through thorough collating and deliberating, we developed six themes (see Figure 3). These provide insights into how participants perceive tailored FRT-based information delivery via Pervasive AR systems across the symmetry and awareness conditions. Although some findings do not directly address our research questions, we believe they contribute meaningfully to the broader dialogue on the ethical implications of pervasive face recognition and are therefore reported with equal importance.

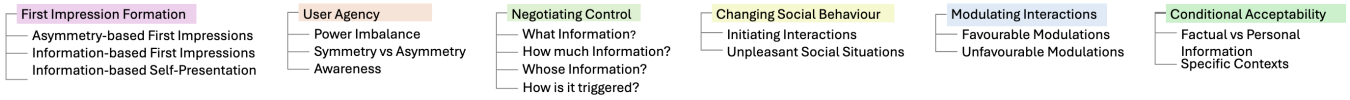

Figure 3: Thematic map illustrating the derived themes.

The themes with accompanying quotes (names pseudonymised) are presented below,

4.1 First-Impression Formation

This multi-faceted theme compiles our participants' insights into how FRT-based information about others via Pervasive AR systems will influence their first impressions of those detected. The dimensions aggregated under this theme not only relate to research question 1 (RQ1) but also provide broader insights into first impressions and self-presentation with pervasive face recognition. **Users regard partners who see more information in *aysmmetric* interactions untrustworthy.** Participants view partners who see more information about them via pervasive face recognition as dishonest.

> Quinn: *"It would make me feel like you'll be the type of person that will rely on external information about me, rather than actually getting to know me. So then that will make me feel untrustworthy of you."*

This participant's impression of their partner, who received asymmetrically more information, is less favourable. They consider this partner to be showing a lack of effort to make an actual connection.

Users conceive an impression of their partner based on the information they see. In more general terms, participants agree they will form first impressions of others purely based on the information they see about them, e.g.,

> Ross: *"I feel when you're presented with information about someone, and ...before even talking to them, you read what's going on. You already start making your own preconceived notion of who they are, and you already start to judge their character."*

This participant believes that the information shortens the process of getting to know someone. Echoing on the previous facet that the information serves almost as a *cheat code* to creating an impression of another. Meanwhile, participants drew parallels between how we form impressions without pervasive face recognition and with pervasive face recognition. The following quote is an example of that,

> Gracie: *"I don't think [first impressions based on the information is] any different to having their social media account open or just the basic way that we look at people. ... Now I'm judging them based on the cues that I see on the glasses, instead of what kind of shirt they're wearing."*

Participants identify that forming impressions based on face recognition information is only an extension of their usual behaviour, where they take external factors such as normative status symbols into consideration when forming an impression of someone.

Users present themselves differently based on what others are seeing about them. There are two sides to first impressions; the first is the construction of first impressions, which we reported on above. We further asked participants how they will present themselves to others to elicit a certain impression, will change with this technology. Some participants believe that the knowledge of others seeing information about you (*awareness*) will lead you to present yourself more in a way that fits what they are seeing about you.

> Violet: *"It also depends [on the] stage of information because if it's only professional information, you kind of present yourself in more of a professional manner. If you can see more [of] the social information, you present yourself in a social, more open, generic manner."*

Participants agree that awareness of what information others are seeing about them will guide them to more strongly project that side of themselves. On the other hand, some participants believe they will not change how they present themselves regardless of the technology.

> Daniel: *"I think I'd present myself just like how I am."*

These participants believe that while the information creates a stronger identity, it only adds to their self-presentation and therefore, does not require them to change the way they already present themselves.

The next two themes aggregate dimensions that relate to research question 2 (RQ2), which explores users' perceived control when using pervasive face recognition. Control and agency are two complementary aspects that are often discussed in terms of how control empowers agency. Rotter[54] claim that those who believe they are in control are more likely to act autonomously—agency. Although we had sufficient evidence to merge the following two themes, we refrained from doing so to avoid oversimplifying our findings.

4.2 User Agency

This category reports the effect that asymmetry of FRT-based information has on the user's sense of agency. **Asymmetric information leads to a disparity in agency.** Directly relating to RQ2, the effects of information symmetry on users' perceived sense of control, participants express that the asymmetry leads to a "power imbalance", causing a conversation to be more one-sided, indicating a lack of agency in that conversation for the participant who is seeing less information.

> Emily: *"I would feel quite uncomfortable in that exchange, and I would feel like there's a power imbalance where you have all this information. We're not on the same level. ... Which could kind of potentially create a one-sided conversation."*

Symmetric information is preferred. Owing to the concerns discussed previously, participants favour symmetric information delivery as opposed to asymmetry in social interactions.

> Lukas: *"I would be most happy if we had the same amount of information. But then, if someone wanted more information, then I would want more information. I would want it to be balanced."*

On the contrary, some participants feel that information asymmetry is not concerning, viewing it as similar to real-life interactions where individuals vary in how inquisitive or engaging they are, prompting others to share more or less in response.

> Mary: *"I think some people are more curious than others naturally. So I would expect a different sort of level from different people as to how much they want to know upfront."*

Although helpful, awareness is not control. Commenting on awareness of knowing how much information an individual is seeing about another, some participants convey that it is helpful.

> Brian: *"I feel like it [awareness] would help a bit. Because at least, you know that they're seeing more about you than you are about them. So you're kind of aware of that, and you can behave according to that knowledge."*

However, the majority of the participants agree that awareness alone is not enough. Especially because the participants cannot change the information they "share" or even see exactly how much the other person sees.

> Anthony: *"I['d] rather choose to have the authority to decide what information of me is being shown, than the indicator. ... I just want to make sure that my information that shows, is decided by me, not by the person who is looking at me."*

In the next theme, we report our findings on broader aspects that affect users' perceived control with pervasive face recognition systems. This theme introduces additional layers to the previously reported theme, user agency.

4.3 Negotiating Control

Participants' need for control was a prominently discussed theme during the interviews. This multifaceted theme encompasses all the areas and aspects participants express they need control in when using FRT-enabled Pervasive AR systems. This section discusses different attributes of perceived control that the participants focus on, including areas of the system that the participants think lack user intervention and control. Interestingly, participants also suggest several mechanisms to ensure control. Therefore, along with participants' concerns regarding a lack of control, we also report their recommended mitigations.

Control of what information is shared. Firstly, participants express the importance of information sharing being consent-based, with explicit control over exactly what is shared about them with others instead of showing scraped information about them from the internet, which creates the risk of inaccurately presenting their personality or constricting them to be presented as just a few facts displayed by ignoring their other personal qualities.

> Adam: *"I don't think [displaying scraped information] a good thing because you should be able to choose what someone sees about you and how you [are] perceived by someone else wearing glasses. ... If it's consensual for all parties involved, I think it'd be a good thing."*

Control of information volume. Secondly, participants highlight the importance of controlling how much information is shared. Participants believe that the amount of information displayed is exorbitant for a first meeting with a stranger because information once shared cannot be taken back and thus should be done responsibly.

> Gracie: *"I can't come up with a good reason why the public should have every bit of information that's on me."*

Participants suggest several control mechanisms to ensure control over how much of their information is exchanged. They suggest only delivering basic information or revealing more information as the relationship matures.

> Shawn: *"If you could modify it to make it, only certain bits are displayed for every first encounter. And if you see the person more than a certain amount of times, it displays that much [more]. But otherwise, it's just too much. I don't think I would want to see everything everyone's done."*

Furthermore, the concern about information volume includes how much information the user receives at once and how it becomes redundant after repeated interactions.

> Quinn: *"It was good [to] start off [the] conversation, but then after you carry on with the conversation, the information was redundant just staying there."*

Participants suggest that this would be an instance in which tailoring what you see about another would be beneficial.

> Hannah: *"I actually think that's a good concept [tailoring what information you see about others]. You can say, 'Okay, I don't want to have that much information, because it's overwhelming to me.' "*

Control over who is detected. Thirdly, participants believe that only other users should be detected and non-users should remain anonymous.

> Sebastian: *"It would be a better system if it was done based on the fact if you're wearing a pair, another pair might recognise that individual user [and] display their information, but if they're not, they're not involved."*

Control of the information delivery mechanism. Finally, participants highlight the importance of controlling how face recognition is triggered.

> Jason: *"At first, I thought it was really scary having all that information available. But then I realised inherently, people can just get that [information] through social media anyway."*

Although participants identify that the information they receive about others is similar to what they will find if they are looking someone up, they claim that the unpromptedness of the information delivery is problematic. Highlighting that looking someone up is a conscious and active decision.

> Brian: *"Having that information available just as the default is quite different from having to actively go and look for it. Because, if you go look for it, you've made an active decision to kind of stalk this person."*

The next themes compile dimensions that contribute to answering RQ3, which explore how pervasive face recognition systems delivering tailored information are ethically judged.

4.4 Changed Social Behaviour

In this theme, we identify different aspects of users' social behaviour that participants believe will change with the regular use of FRT-based Pervasive AR systems.

Redefining conversation initiations. Participants state that receiving information about others and the knowledge of others seeing information about them will change how they initiate conversations (Cf. [33]); for example, participants believe that it will be normal for users to already know about each other on first meetings.

> Hannah: *"Because you could read [the displayed information], and you could just directly ask them [questions], and that's just something we need to get used to. ... It's completely different [to] the way we communicate."*

Detrimental social ramifications of pervasive face recognition. Firstly, participants express that receiving information about others can result in awkward situations, such as strangers approaching them unexpectedly, feeling like stalkers in social settings due to access to others' personal information, or even being excluded from interactions because of that perception.

Joey: *"I think in social settings, people wearing those kinds of glasses would be a little bit shunned."*

The second type of potentially negative social implication that can arise from FRT-based information exchange is making those detected via the glasses vulnerable to dangerous circumstances, such as being singled out, attacked, manipulated or stalked.

Jason: *"You see someone you like, you look at them, and then you know everything about them, and then you just follow them."*
Ross: *"I think it'd be used to manipulate people, knowing what people's interests [are] ...is really useful if you want to flatter someone and get something that you want. If the wrong people have the tool, then ...they'd be able to hone down on insecurities."*

Participants also note that the information they read about others can result in them feeling insecure or vulnerable about themselves in comparison.

Monica: *"For example, you meet a billionaire across the street, and you see his whole portfolio, and you have a smaller portfolio. I think it might lead to overthinking.*

Similarly, participants believe that the insecurity can stem from others manipulating their own information to falsely seem more attractive or appealing than they really are.

Ross: *"If [the system] pulls stuff from social media, then that's easy to fake. In the case of a bad person using this, you can make yourself [look] like a really trustworthy person, and then use that front to take advantage of people."*

Furthermore, participants believe the information they receive from the system will allow them to modulate their interactions with others. The following theme elaborates on the different facets of this.

4.5 Modulating Interactions

Participants convey that the information they receive about others will help them modulate their interactions. This theme has both favourable and unfavourable aspects to it.

Interactions guided by the information. Participants express that the information can, in general, help steer conversations (Cf. [42, 40]).

Brian: *"It's nice to be able to see where your common ground might be. It helps to know what kind of questions to ask."*

Furthermore, they believe that the information will help naturally shy individuals to take the lead and confidently engage with others.

Edith: *"It made me feel a bit more confident asking questions. I'm generally an introvert. Wearing the glasses, I was quite [an] extrovert."*

Interactions forced by asymmetry. Some participants believe the asymmetry of information can force them to interact with others purely because they are seeing information about them.

Daisy: *"I think [the asymmetry] would change who the more vocal people are within a conversation. For example, if you saw all this information on them, it might force people into a conversation."*

Screening people based on information. In contrast, some participants view the information exchange more as a hindrance to a good, quality interaction. They state that the list of information is so saturated that it can lead to completely avoiding/ filtering out a person purely based on the information seen.

Haley: "If you see something that doesn't really interest you [...], [then] you might be less likely to talk to them. You're [now] more likely [to] just talk to people who [have] similar interests, than getting out more."

Participants note both pros and cons of filtering people out this way. The following quotes highlight these opposing views on filtering people based on the information displayed about them.

Sebastian: *"You might see that they're a fan of the Crusaders [sports team], and you just don't want to talk to them, but they might be a really lovely person."*
Rachel: *"I attend a conference, and someone is in my area, I know instantly, and I wouldn't need to talk to many people to find out what their research idea is."*

Information overload leads to superficial interactions. Participants convey that the information makes interactions seem perfunctory. Adding that it can structure the conversation in a way that is similar to checking things off a checklist, while not attempting to learn more about the other person in depth, because everything is already displayed via the glasses, making the interaction superficial. This results in partners seeming detached from the interaction.

Mia: *"Just being given that information would make you less reliant on actually putting the effort into remember[ing] things. I'll be less likely to know and to remember any meaningful information about someone if, whenever I looked at them, it was just there."*

In contrast, participants believe that others having access to extensive information about them during interactions compels them to be more honest in conversations.

Flynn: *"If everyone sees everything about everybody, then you know nobody is lying. I mean, more honest."*

Besides the previously reported concerns about FRT-based Pervasive AR systems, there are certain aspects that participants deem acceptable. The following theme focuses on this dimension.

4.6 Conditional Acceptability

Acceptability based on the type of information. The majority of the participants favour only receiving general factual information rather than personal information from Pervasive AR systems.

Ross: *"I can imagine the glasses being used for other things, like you could set a timer. I don't think that's inherently harmful."*

Some participants are comfortable with having their information delivered to other users because the information is already out there. Further stating that the information that already exists is, in a way, already curated by them.

Mary: *"I'd be quite comfortable with it. I don't really have anything to hide. ... I think I'm out there a wee bit anyway, in general."*

Context-based acceptability. Some participants consider the disclosure of personal information acceptable only in specific contexts, such as conference settings, medical emergencies or for security.

Jason: *"If someone is dying on the street ...you don't know their personal information, you could look at them [and] figure out what their name is."*
Gracie: *"Well, if they're a danger, they have a criminal record or they've been associated with terrorist groups, maybe you'd want to know that for the safety of your child if they show up for an interview to be your babysitter."*

Meanwhile, certain participants thought that, outside of specific uses, the technology was unnecessary for everyday use.

> Brooke: *"If you're sitting having one-to-one conversations, it will be nice to have the glasses. [But] walking past, you see all these people will be distracting."*

In summary, we developed six themes that address the influence of FRT-based Pervasive AR systems on, 1. *First Impression Formation*, discussing first impressions and self-presentation. 2. *User agency*, discussing users' sense of agency and autonomy in social interactions. 3. *Negotiating control*, discussing the influence the information exchange has on users' perceived control. 4. *Changed Social Behaviour*, discussing the potential behavioural and social changes and challenges. 5. *Modulating interactions*, consolidating dimensions of how users shape their interactions with others based on the information. 6. *Conditional acceptability*, accumulating acceptable contexts of use for the technology.

5 Discussion and Future Work

The field of AR is seeing a rapid emergence of new devices such as the Brilliant Frame[5], Snap Spectacles[6] and AndroidXR Gemini wglasses[7]. These new-age AR glasses, paired with advanced face recognition systems such as Clearview AI[8] or lightweight PimEyes, would mean pervasive face recognition is not far off. When an afternoon's simple coding allows a group of students to scan and identify people in a busy city [24], such implementations need to be done responsibly with consideration for everyone involved. The most meticulous way to approach an omnipresent technology such as pervasive face recognition is by first identifying its repercussions and the aspects of a user's life it affects. Therefore, we believe this work is uniquely positioned to lay the groundwork for that investigation. We focused on how tailored face-based information delivery via Pervasive AR would affect first impression formation, self-presentation, perceived control and overall ethical implications.

RQ1: How does the symmetry of tailored information delivery affect users' first impressions of others?—in the *First impression formation* theme, we report that while it is not different from forming your perception of someone based on certain status symbols, the information seen via Pervasive AR about someone else does, in fact, influence how we view that person (Cf. [48]). More importantly, beyond the content of the information itself, as assumed, the *symmetry* of information exchange also influences our impression of other users. When users receive significantly more information than they share, they are more likely to be perceived as unwilling to engage.

With the use of this technology, users will rely on information-based impression formation. We reported in our theme *Modulating interactions* that users will use the information they see about others to decide whether or not to interact with those persons, indicating that the users' impressions of others in that particular social situation are solely based on the information they receive about that person, preceding any real interaction. Furthermore, we recognised that it is just as important to focus on the effect FRT-enabled Pervasive AR has on the individual who presents themselves in social situations (Cf. [20]). In the *First impression formation* theme, we reported that users will alter their presentation based on the type of information that is being presented to others about them.

Similarly, participants voiced their explicit need to *control* the information shared about them to preserve their true personality and presentation in social contexts. Thus, opposing the delivery of scraped information. This brings us to our second research question, **RQ2: How does the symmetry of tailored information delivery in social interactions affect users' perceived control?** While our findings under the theme, *Negotiating control*, support our assumption of perceived control being a critical factor in FRT-based information exchange via Pervasive AR, it cannot be discussed in isolation but instead along with our theme, *User agency*. Answering RQ2, our findings suggest that users will need control over how much information and what information is shared with others. More importantly, these themes report that less information will always be preferred.

"A bell once rung cannot be unrung". The importance of controlling the amount of information stems from how once shared, information cannot be taken back (Cf.[64]). Therefore, it would be prudent to implement a gradual reveal of information. Moreover, users will prefer symmetric information exchange to ensure that interactions are not skewed. As reported under the theme *Conditional acceptability*, the use of FRT-enabled Pervasive AR systems can be appealing in certain controlled contexts (see [11, 15, 30]. Furthermore, as hypothesised, users' sense of control is critical and influences the perceived acceptability of FRT-enabled Pervasive AR systems. Dynon[15] states that users' perceived sense of control is key to accepting FRT on personal devices. However, Brandimarte et al.[8] state that increased control can be counterintuitive to ensuring user privacy as it sometimes leads to disclosing more personal information.

RQ3: How is the delivery of tailored information about others via Pervasive AR ethically judged? In this study, we subscribe to the work of Stahl, Timmerman and Flick [57] as a scaffold to answer this research question. Thus, we relate the issues we qualitatively identified to explicit morality [56] under their defined categories: 1. *impact on individuals*, 2. *consequence to society*, and 3. *uncertainity of outcomes*. The majority of the issues we identified relate to the category of ethical issues that have an *impact on individuals* who use FRT-based Pervasive AR systems. This category identifies issues that affect autonomy, identity, treatment of humans (systems that manipulate and mislead individuals), security, and privacy.

Amongst the themes we developed, the *Negotiating control* theme and the *Changed social behaviour* theme predominantly inform us of ethical issues affecting individuals [57]. The larger share of the concerns reported under *Negotiating control*—such as the information being scraped rather than curated by each user, automatic information delivery, or recognition of non-users—shifts the control from the user to the Pervasive AR system, raising numerous *autonomy*-related ethical issues. Furthermore, awareness did not improve users' sense of control as it was not actionable, further worsening users' *autonomy* and posing ethical challenges. Nonetheless, this finding contributes to answering **RQ3.2: How is the asymmetric delivery of tailored personal information judged when users are made aware of the existing asymmetry?**

We identified two key ethical concerns related to *identity*. First, feelings of insecurity based on what a user is seeing about others or feeling like a stalker due to asymmetry (refer to theme *Changed social behaviour*) as a result of this technology are ethically concerning. Second, although users found the idea of a *"remembrance agent"*([52]) to be useful, there were concerns about reduced cognitive load. The concept of *Digital dementia* [46] applies here. When all one needs to remember about another is constantly presented to them via AR, the need to actively recall details diminishes, potentially weakening memory-related functions. This concern was previously also reported by Regenbrecht et al. [51].

Issues such as potential manipulations, misleading, stalking and discrimination of others based on personal information received via FRT-based Pervasive AR systems highlight ethical issues relating to *treatment of humans* and *security*. Furthermore, under *treatment*

[5] www.brilliant.xyz/products/frame

[6] investor.snap.com/news/news-details/2025/Snap-to-Launch-New-Lightweight-Immersive-Specs-in-2026/default.aspx

[7] blog.google/products/android/android-xr-gemini-glasses-headsets/

[8] www.clearview.ai/

of humans, security and *privacy* categories, participants expressed concerns regarding the general privacy violations by these systems. Privacy and security concerns related to always-on systems continue to be extensively investigated from a range of perspectives such as in terms of general social implications [45, 51, 53, 66], its effect on secondary actors [6, 31, 69], technical implications [7, 43] and design recommendations [10, 13, 32]. While we recognise the significant ethical implications of traditional privacy, their in-depth exploration is beyond the scope of this work. Instead, we focus on a more context-specific privacy and security concern our participants raised—the lack of explicit consent when one's personal details are shared with another via Pervasive AR. This concern qualifies as an ethical issue relating to both *treatment of humans* and *privacy*, particularly when the shared information is scraped.

Moreover, the constant data collection by always-on systems implies *consequences for society* as a whole. Stahl et al. state technologies that continuously monitor individuals—sousveillance, to be ethically questionable. Under the same category, they identify issues that result in inequity and inequality—*Digital divide*. As we have established, FRT-based Pervasive AR creates asymmetrical information exchanges among users. The asymmetry would lead to power imbalances in interactions, leading to a certain group having reduced agency, which poses ethical implications. That said, this finding contributes to answering our sub-research question, **RQ3.1: How is the delivery of tailored personal information in social interactions judged when the amount of information accessed and shared is symmetric?** Similar challenges from asymmetrical information exchange have previously been observed by Eghtebas et al. [16], Regenbrecht et al. [49], and Perera et al. [45].

Furthermore, participants believed the information inequity created by not having Pervasive AR glasses would put them at a disadvantage, forcing them to adopt the technology. While this particular concern does not relate to our research questions directly, it discusses a valid ethical dilemma pertaining to Pervasive AR. This is a widely discussed challenge of ubiquitous systems [11, 16, 45, 49]. Reporting on this issue, Chung et al.[11] and Perera et al.[45] have stressed the importance of implementing a sharing mechanism between users.

This issue of inequity is more critical in pervasive face recognition as the issue arises from a partner receiving more personal information about the user than they are sharing about themselves. This relates back to the need for consent and actionable awareness. Moreover, in their report for XR4Human, Stephane et al., [58] identify informed consent, equity, social fairness and privacy and security, among others, to be critical ethical considerations for Extended Reality (XR), which includes AR.

The final ethical issue we discovered relates to challenges arising from unforeseen technological limitations, under the category of *Uncertainty of outcomes* [57]. When information is being scraped from the internet, there is a risk of the information being outdated or incorrect due to FRT limitations, leading to inaccurate presentations of those detected (as reported in *Negotiating control*). According to the Stahl et al. framework, such inaccuracies pose an ethical dilemma. Eghtebas et al. [16] state in their work different contexts of how a user could be misrepresented or overexposed based on their online persona and suggest having information brokers that act on the user's behalf to safeguard the accuracy and access of data.

Future Work— Overall, some participant comments may be attributed to the artificial experiment setting. Participants mentioned not noticing or adapting to the asymmetrical information delivery quickly, possibly due to the security of knowing they were in a controlled experiment or that the information was self-submitted. We see an opportunity for pervasive face recognition to be explored in a more ecologically valid environment to reveal additional dimensions of interest that affect pervasive face recognition and its ethical implications.

Moreover, participants found the lack of eye visibility through the glasses made it difficult to read emotions, preferring a more subtle design of glasses for daily use. These concerns stem from the chosen device for this study, Snap Spectacles. In future, AR glasses with transparent lenses, such as the Frame by Brilliant Labs, could negate these issues, thus warranting further investigations.

Besides the WEAR scale intended for wearable technology, the other measurements we used, Perceived Control questionnaire—designed for analysing interfaces and Perceived Trustworthiness questionnaire—intended for psychological analyses, reported poor reliability in our context. Thus, there is potential to operationalise these variables with measurements that better suit Pervasive AR systems. Although our sample size was consistent with similar studies in the domain, a larger sample may have yielded some significant results with these measures.

While opening the dialogue, the ethical implications we report create an opportunity for future work exploring how different design guidelines and mechanisms can be harnessed to alleviate these concerns. Thus, more work is needed to identify how each issue can be best addressed while keeping users' interests in mind.

6 Conclusion

In conclusion, as Pervasive AR continues to transition into a wearable everyday technology that delivers contextualised information in real-time, it is essential to recognise the implications that the combination of two technologies, FRT and Pervasive AR, will bring about. This transformative turn of technology will change our interpersonal behaviours, in ways that can have ethical implications that affect users and those around them. Our six themes offer an informed perspective into these issues and concerns that need to be proactively addressed to reshape Pervasive AR into a technology that acknowledges users' core values. FRT-enabled Pervasive AR should merely serve as an aid to its users instead of undermining the integrity of meaningful social connections. Thus, it should be implemented to serve the benefits identified while mitigating negative consequences such as disruptions to users' self-perceptions, weakened sense of control, social power imbalances, and exploitation of others enabled by the technology. We believe informed consent and information equity can address the key issues pertaining to these ethical challenges.

Author Contributions

Kushani Perera: writing- original draft, conceptualisation, methodology, software, formal analysis, investigation, data curation and visualisation. **Holger Regenbrecht**: writing- review & editing, conceptualisation, methodology, formal analysis, funding acquisition, and supervision. **Nadia Pantidi**: writing- review & editing, conceptualisation, methodology, formal analysis, and supervision. **Tobias Langlotz**: conceptualisation, methodology, visualisation and supervision.

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