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# Shared Privacy Concerns of the Visually Impaired and Sighted Bystanders with Camera Based Assistive Technologies

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Camera based assistive technologies can provide people with visual impairments (PVI) visually derived information about people in their vicinity. Furthermore, the advent of smart glasses offers the possibility of not only analyzing visual information in front of the wearer, but also behind them through an extended field of view. Although such ‘visually available’ information can enhance one’s social interactions, the privacy and ethical implications for automated judgments about bystanders especially *from the perspective of PVIs* remains underexplored. To study the concerns of both bystanders and PVIs with such technologies, we conducted two online surveys with visually impaired participants as wearers (N=128) and sighted participants as bystanders (N=136). Although PVIs found some types of information to be improper or impolite (such as someone’s weight), our overarching finding is the *shared* ethical concern between PVIs and bystanders related to the fallibility of AI, where bystanders can be misrepresented (algorithmically) by the devices. These mischaracterizations can range from occasional, unexpected algorithmic errors (e.g., errors in facial recognition) to the questionable use of AI for determining subjective, social constructs (such as gender). Based on our findings, we discuss the design implications and directions for future work in the development of camera based assistive technologies while mitigating the ethical concerns of PVIs and bystanders.

CCS Concepts: • **Security and privacy** → **Usability in security and privacy**; • **Human-centered computing** → **Empirical studies in accessibility**.

Additional Key Words and Phrases: privacy, visually impaired, augmented reality, AI-ethics, fairness and bias

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## 1 INTRODUCTION

Camera based assistive technologies offer the promise of simplifying everyday visual tasks for people with visual impairments. For example, such assistive technologies can be used to identify objects and colors [7], read documents [1], and navigate through places [6, 54, 129]. With the advancement of computer vision, however, assistive devices are now providing more complex features to socially interact with others by analyzing people around them. Not only are such

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technologies being used to recognize faces [4, 121] and facial expressions [9] but also to ascertain other attributes of people (e.g., gender, age, and height) [9]. These capabilities are now available as commercial offerings of wearable glasses such as OrCam [4], Aira [2], and eSight [8], which have been gaining popularity amongst people with visual impairments (PVIIs). To fill the gap where AI is error-prone, PVIIs have also been seeking help from professional agents [2] and volunteers [3] to obtain higher-quality information about their surroundings.

The increasing demand for such assistive technologies, and their fallibility, raises ethical and privacy concerns for their general use. A large body of work has shown how AI-based recognition of subjective constructs such as gender, race, and emotion can replicate human biases in automated systems [28, 42, 67, 68, 77, 112]. Hamidi et al. reported how identifying gender through facial features can challenge the autonomy of transgender people and reinforce gender binary attitudes [67]. Furthermore, their use can adversely affect marginalized populations (such as people of color and transgender people) [42, 55, 77, 105, 125] by increasing inequality [102]. In the context of algorithmic errors, prior work has also highlighted how facial recognition systems are incorporated within systems of policing and surveillance where misclassifications can create significant problems (e.g., if the algorithm wrongfully identifies someone as a suspect) [14, 68]. Therefore, the adoption of AI-powered recognition of people's characteristics raises ethical implications for mischaracterizing bystanders and heightening risks for marginalized groups.

The design of camera based assistive technologies can raise additional concerns through the scope of information that can be analyzed. For example, Ahmed et al. found that bystanders may be uncomfortable if assistive devices provide PVIIs information beyond a sighted person's 'natural range' [21].<sup>1</sup> Bystander concerns with such technologies is not surprising; prior studies have found significant concerns raised by bystanders regarding the information captured and shared by augmented reality glasses [50, 81, 87]. Although researchers found higher social acceptability for assistive devices [59, 101, 107], there still remains stigma against the use of such glasses and bystanders remain concerned about various uses by PVIIs such as extended field or views or access to information that is not 'visually available' to sighted people [21].

In this work, we take the position that although bystanders' concerns about the use of assistive cameras can be stigmatizing and unwarranted, there remain *shared* ethical and privacy concerns between PVIIs and bystanders related to the fallibility and improper use of AI. PVIIs may also care about the privacy of bystanders orthogonal to concerns about being stigmatized. Hoyle et al. report on feelings of 'propriety' [111] by (sighted) camera wearers in the context of 'lifelogging' [74], and sociologists have identified the concept of 'tactful/civil inattention' [29, 62] where people deliberately ignore private information that may be available to them. Thus we might also expect PVIIs to consider some types of information more 'proper' than others in addition to the issue of algorithmic mischaracterization of bystanders.

In this paper, we focus on the following research questions:

**R1:** (Fairness) What visually available information about bystanders do PVIIs consider *useful* from a 'Front' vs. 'Front-Back' field of view (FoV) and why?

**R2:** (Propriety) What visually available information about bystanders do PVIIs consider proper or improper and why? How comfortable are PVIIs with obtaining such information in these views from camera based assistive technologies?

**R3:** (Shared concerns) What are the shared concerns of PVIIs and bystanders in the context of camera based assistive technologies?

To answer these research questions, we conducted two online surveys of US participants, with 128 visually impaired participants (as users of assistive technologies) and 136 Amazon Mechanical

<sup>1</sup>The natural vision range for a sighted person is a 200-degree binocular field of view [12].

Turk (MTurk) participants (as bystanders) examining two reactions (comfort and usefulness) in the context of two different fields of view in a social gathering scenario. We conducted both quantitative and qualitative analyses to understand the information sharing and accessing preferences as well as concerns of participants from both surveys.

This article is an extended version of own work presented at the 2020 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS 2020) [24]. In this extended article, we augment the Method section with a discussion on how to avoid social desirability bias and bot-based responses in online surveys. We added new quantitative findings that show that bystanders consider it more reasonable to share behavioral information with PVIIs compared to visually available information which contrasts their comfort level preference. We include additional qualitative findings of visually available information needs reported by our PVI participants. We also expanded our Discussion section that addresses the ethical challenges related to identifying subjective information (e.g., gender, race, and emotion) through AI-based assistive systems. We also include the following suggestions to improve the design practices of camera-based assistive technologies: 1) including context in the design process; 2) setting a standard for AI-generated descriptions; 3) increasing the social acceptability of assistive systems; 4) adding propriety policies; 5) conveying confidence information and including feedback from PVIIs; and 6) enforcing algorithmic accountability, transparency, and explainability while designing assistive technologies.

## 2 RELATED WORK

In this section, we present related work on the information requirements of PVIIs about bystanders in their vicinity, the social acceptability of assistive devices, and fairness issues in accessing information through assistive technologies.

### 2.1 Information requirements of PVIIs

The difficulties to access visually available information about the people in their vicinity could lead to social isolation [80, 83, 127] or may cause safety and security risks and concerns for people with visual impairments —Ahmed et al. reported that the number of people nearby and their identity, proximity, and activity are the most important information desired by PVIIs to ensure their safety and security [19, 20, 22, 40].

Specific to information about bystanders, Zhao et al. prioritized the information needs of PVIIs into: identity, relative location, physical attributes, and facial expression [132]. Krishna et al. similarly identified facial expressions, identity, and body gestures as the top categories of needed information by PVIIs in their social interactions [83]. Other works also investigate the necessity of facial expression [26, 103, 109, 122], relative location [57], identity [20], gaze [19, 115], and demographics [103] of bystanders. Various camera based assistive tools as well as smart glasses have been developed for PVIIs to help facilitate social interactions by recognizing faces or facial attributes of people in their vicinity [46, 79, 82, 84, 131, 132]. Some assistive applications additionally provide the approximate age, gender, and activity of a person along with face and expression recognition [4, 9]. PVIIs also use professional agents or volunteer based assistive tools to be aware of their surroundings and other people in their vicinity [2, 3]. The main focus of all of the above is to provide PVIIs information that establishes ‘equality’ with sighted people, in terms of what is typically observable by a sighted person.

Moreover, PVIIs also desire to know whether they are being followed in public places (to ensure their physical safety) or whether somebody is looking at their monitor (to protect their security) [19, 22, 70]. Therefore, more research is needed on the information needs of PVIIs beyond a sighted person’s field of view. One of our goals is to understand the perspective and comfort levels of PVIIs when accessing and sharing such information. In particular, although the various types of

information mentioned above may be useful, more research is needed to study the interplay between what is perceived as useful and what PVI consider fair and appropriate in seeking.

## 2.2 Social acceptability of assistive devices

As PVI continue to leverage assistive technologies in their social interactions, one must also consider the social acceptability of such devices. Lee et al. suggested to understand the perspective of both PVI and bystanders to increase the social acceptance of wearable cameras [86]. Prior works have investigated social acceptability and privacy issues for assistive technologies from the perspective of their users [58, 87, 92, 95, 128]. Garg et al. found that the adoption of assistive technologies by older adults depends on the perceived usefulness of the system [58]. Shinohara and Wobbrock observed how participants avoided using assistive technologies because of the associated social stigma [119]. However, beyond the concerns of being stigmatized, PVI might also be concerned about the privacy of bystanders and may like to access only the information they consider appropriate. Sociologists observed similar behaviors where people ‘tactfully’ ignore private information about others that are available to them to respect the privacy of others [29, 62]. Hoyle et al. reported that lifeloggers with wearable cameras show ‘*propriety*’ [111] behaviors by not sharing certain photos of other people or turning off their lifelogging cameras [74]. Akter et al. observed that PVI are more concerned about the privacy of bystanders than their own while using image based, human-assisted question answering services [25].

To understand the perspective of bystanders, Denning et al. studied people’s reactions to the presence of augmented reality wearable devices [50]. They found that various factors can influence a bystander’s perspective towards augmented reality devices such as discreetness, context, purpose, and the method of recording. Singhal et al. similarly explored bystanders’ reactions to video-capture in public spaces by Google glass [120]. They also found that bystanders preferred to be asked for permission before being recorded through such devices. Koelle et al. examined users’ and spectator’s perceptions about data glasses and observed several factors such as the type of device (novel or established), gender of the wearer, and knowledge about how the information would be used can influence the attitude of bystanders [81]. Nguyen et al. reported concerns relating to information privacy when people are video recorded including notification or consent, improper access, and unauthorized secondary use [100]. Hoyle et al. reported extreme cases when bystanders were avoiding interactions with the device wearer [74].

In the context of assistive devices, researchers reported that bystanders are indeed more positive about sharing information with people with disabilities as compared to people without disabilities [21, 107]. Ahmed et al. found that bystanders expressed hesitance to share information with PVI through interactions that were not ‘natural’ from a sighted person’s perspective [21]. In this study, in addition to studying the perspective of both PVI and bystanders, we investigate the impact of sharing information on social acceptance based on two fields of view (Front and Front-Back).

## 2.3 Fairness and equity in information access

Assistive technologies for PVI are increasingly leveraging advances in computer vision and machine learning to provide access to information that is already available to sighted people including facial expressions [4, 9], gaze [108, 109], and activity [2, 9]. However, the intention to provide ‘equal’ access to information raises the question of fairness in the context of assistive technologies. Prior works discussed AI-related fairness challenges in the context of accessibility and the ethical implications to decide what information AI should provide to users [34, 42, 55, 97]. Findlater et al. focused on balancing the privacy concerns of the primary users and others raised by sensory augmentation. Ahmed et al. raised the question of attaining ‘equality vs. equity’ for

PVIs in the context of assistive glasses [21]. According to their study, bystanders are more lenient when providing equality to PVIs as compared to equity. Although they are willing to share more information with PVIs compared to sighted people, they are willing only ‘up to a limit’. Similarly, PVIs may consider some visually available information more important than others (e.g., facial expressions more than age). In the context of bystander privacy, Ahmed et al. found that even though bystanders can easily access information about people behind them, they are hesitant to share such information with PVIs since it does not mimic natural vision [21]. However, PVIs may need access to such information in their daily lives to overcome their accessibility barriers. Although our work focuses on points of agreement between PVIs and bystanders, more work is needed to address and counter concerns of bystanders arising out of stigma. Our work sheds light on such fairness issues related to the field of view preferences of PVIs and bystanders.

### 3 METHOD: SURVEY STUDY

To answer our research questions, we conducted two online surveys. In the first survey, we focused on the needs and concerns of PVIs with receiving information about bystanders from augmented reality devices (such as Google Glass or Microsoft HoloLens). In the second survey, we explored the concerns of bystanders about sharing such information with PVIs using augmented reality devices.

#### 3.1 Experimental condition: Field of view

In the survey, we considered two between-subjects experimental ‘field of view’ conditions based on whether the glasses could provide information from a) front of the glasses (*FoV Front*), or b) all directions, including from behind the wearer of the glasses (*FoV Front-Back*)<sup>2</sup>. We choose a between-subjects experimental design to avoid carryover effects across conditions [45], i.e., we wanted to avoid any bias of participants’ responses relative to their responses to the previous FoV condition if the study were conducted within-subjects. It is possible that participants would be primed to express more privacy concerns with the Front-Back FoV condition after answering questions for the Front FoV condition. With a between-subjects design, differences between the two conditions would yield a stronger result by avoiding validity concerns related to carryover effects.

#### 3.2 Visually available information

Each survey sought to measure the privacy concerns of PVIs when receiving eleven ‘visually available’ information about the bystanders through the glasses.

By visually available information, we refer to information that a sighted person can infer by looking at other people. Our selection of the types of visually available information was grounded in prior studies [21, 83, 132]. Ahmed et. al considered six types of visually available information in the context of bystander’s willingness to share their information: demographics (age, gender, race), height or weight, gaze, activity, appearance, and emotion (happy, sad, stressed) [21]. Krishna et al. reported that facial expressions, identity, and body gestures were the top three information that PVIs need in social interactions but were not always accessible to them [83]. Zhao et al. found that information about whether some one is available for conversation is also important in social activities [132]. Inspired by prior studies, we asked the participants about their comfort levels with receiving eleven visually available information as well as their usefulness: activity, distance, attire, whether the person is alone or available for conversation, emotion, gaze, gender, age, ethnicity, height, and weight.

<sup>2</sup>Although we used different labels (Fov sighted and Fov extended) in the previous version [24], in this extended article we use more intuitive labels.

### 3.3 Dependent variables: Measuring privacy concern

We asked two major sets of questions (within subjects) for each of the two experimental conditions (between subjects). The two sets of questions measured the ‘comfort level’ of receiving or sharing each visually available information, as well as their ‘usefulness/reasonableness’, each using a 5-point Likert scale.

The wording of the description and questions varied slightly based on the two FoV conditions. – ‘Front’ and ‘Front-Back’. When describing the glasses, we mentioned only forward-facing cameras for Front view, whereas for the Front-Back view condition we mentioned both forward and rear-facing cameras. We also asked the participants to assume that the bystander is ‘directly in front’ of them in the Front view condition whereas for the Front-Back view condition they were asked to consider that the bystander is ‘behind them’.

Specifically, we asked two questions to PVIs with a 5-point Likert item for each of eleven visually available information. Each question was followed by an open-text question where we asked the participants to explain the reasons for their selections. We also asked the PVI participants to list additional information they considered useful.

**VQ1.** *How comfortable would you feel about getting various information through assistive glasses about the people [in front of/behind] you?* Participants were asked to select from a 5-point Likert scale ( 1: extremely uncomfortable; 5: extremely comfortable).

**VQ2.** *Please take a couple of minutes to explain your answers. We would like to know why you are comfortable with certain kinds of information and why you are uncomfortable with other kinds of information?*

**VQ3.** *How useful it would be to get information about people [in front of/behind] you through the assistive glasses?* Participants were similarly asked to select from a 5-point Likert scale (1: not at all useful; 5: extremely useful).

**VQ4.** *Please take a couple of minutes to explain your answers. We would like to know why you think some information you selected is more useful than others?*

**VQ5.** *If there is any other information that you may consider useful to know about a person [in front of/behind] you at a social gathering, please describe them briefly.*

For the bystander survey, we asked two questions to investigate the comfort level of bystanders. Similar to the PVIs survey, each question was followed by an open-text question where we asked the participants to explain the reasons for their selections. We considered the same 5-point Likert scale used in the PVIs survey.

**BQ1.** *How comfortable would you feel about a PVI getting various information about you through assistive glasses when they are [facing/facing away from] you?*

**BQ2.** *Please take a couple of minutes to explain your answers. We would like to know why you are comfortable with certain kinds of information and why you are uncomfortable with other kinds of information?*

**BQ3.** *How reasonable it would be for a PVI [facing/facing away from] you to get information about you through the assistive glasses?*

**BQ4.** *Please take a couple of minutes to explain your answers. We would like to know why you think some information you selected is more reasonable to receive than others?*

### 3.4 Organization of the survey

The surveys comprised of 21 questions in both open-ended and close-ended form. Questions such as level and duration of visual impairments were not included in the bystander survey. We organized the survey instruments as follows: (Our survey instruments are available as supplementary materials.)

- Consent form.
- Questions about the participant’s level and duration of visual impairment, which (if any) electronic devices and assistive technologies they use and frequency of usage, and the purposes of using assistive technologies.
- Two field of view conditions based on random assignment (between-subjects), each with two sets of questions about their ‘comfort level’ of receiving/sharing visually available information (such as gender, distance) about people in their vicinity/themselves through camera based assistive technologies and how ‘useful/reasonable’ it is to receive/share such information. The options for each question were presented in random order.
- Six demographic questions (age, gender, race or ethnicity, education, duration living in the United States, and occupation).

### 3.5 Recruitment

We hosted our surveys on Qualtrics (an accessible survey platform) over a period of two months. For the survey with visually impaired participants, we circulated our recruitment sign-up form through email lists of various blind organizations including the National Federation of the Blind (NFB) [11] and the American Council of the Blind (ACB) [10]. We also applied snowball sampling by asking our participants to share our study with others. Participants were asked to sign-up in the recruitment form only if they met the following criteria: participants had to be 1) living in the United States; 2) 18 years of age or older; and 3) visually impaired. Participants who responded through the sign-up form were screened by two researchers and we emailed each qualified participant a unique survey link. Each participant could participate in the survey only once as the link was not reusable. A total of 136 people with visual impairments participated in the survey although some participants did not complete the survey. After removing the incomplete responses, our final sample for the study comprised 128 participants with visual impairments.

Respondents for the bystander survey were recruited from Amazon Mechanical Turk for a ‘15-min survey on information sharing preference with PVIs’. MTurk has been extensively used for conducting privacy and accessibility research because of the ease of recruiting and diversity. [37, 47, 49, 110]. Respondents were required to be 1) residents of the United States for at least five years to control cultural variations [78]; 2) 18 years or older; 3) ‘workers’ of MTurk with an approval rating of at least 98% on at least 1000 completed HITs to ensure a higher quality of responses (details added in Section 3.7.2). We included the responses in the data analysis from the respondents who 1) correctly answered all three attention-check questions; and 2) entered the correct random response code as generated by the survey instrument. We compensated respondents who answered one attention-check question wrong, but excluded their data. After discarding responses from the participants with at least one attention check wrong, we were left with 136 participants (out of 156 participants). Therefore, our participants were spread across the two FoV conditions as follows (Table 1):

Participants	FoV Front	FoV Front-Back
Visually impaired	64	64
MTurk	68	68

Table 1. Participants across field of views.

### 3.6 Compensation and ethical considerations

Conducting an online survey with compensation for each participant brings the risk of abuse from non-visually impaired persons. Therefore, we opted for a raffle-based approach, which has the advantage of stimulating high-quality responses through voluntary participation [25, 39, 41, 63, 75, 104]. A disadvantage of this approach is that not all participants are compensated, and thus it is important that the ‘voluntary with raffle’ nature of the survey be made clear up-front – participants were informed of the compensation scheme in the recruiting materials as well as in the consent form and thus participated voluntarily. After collecting 136 responses, we performed the random drawing and selected 14 (approximately 10%) participants and paid \$20 Amazon e-gift certificates to each of them. We emailed them the link of the e-gift certificates within 3 days of performing the random drawing.

For the bystander survey, each participant was paid \$2.50, whether or not we used their response. Our protocol was approved by our institution’s ethics review board.

### 3.7 Pilot study

We conducted an in-person online survey and a follow-up interview with four visually impaired participants (3 male, 1 female) to identify any accessibility issues of our survey instrument. Three of the pilot participants were blind and one had low vision. Their ages ranged from 25 to 55 or older with full-time employment. Three participants participated in the survey using computers and one from a mobile device. They used Jaws, Voice-over, and Google’s TalkBack as screen readers. The pilot study took around 40–60 minutes for each participant. Participants were compensated with \$20 cash for taking part in the pilot. As a result of feedback received during the pilot, we added a more detailed description of the smart glasses (e.g., discreet but noticeable), how it works (e.g., visual information from the cameras are analyzed automatically with the use of a forward/rear facing camera), how the information is delivered (e.g., earphone), and the accuracy of the information provided (e.g., confidence level).

*3.7.1 Avoiding social desirability bias.* Prior studies have found that various social cues often influence people’s decision-making behavior [21, 48, 56, 90, 114]. Crowne & Marlowe defined the following behavior as social desirability bias – “the need of subjects to obtain approval by responding in a culturally appropriate and acceptable manner” [48]. In self-reported studies, there is a tendency for respondents to present themselves favorably with regard to social norms rather than how they might behave or actually feel or believe in real-life [21, 56, 90]. Some factors that influence social desirability bias are the desire to maintain a good impression, self-deception, and trying to gain social approval [90]. Social desirability bias can lead to the reporting of spurious or misleading research results [56]. Prior works identified several techniques to avoid social desirability bias from the responses such as anonymous survey administration, neutral question and prompt wording, indirect questioning, randomized response, and nominative techniques [85, 96, 99, 124].

Building on these prior works, to avoid social desirability biased responses from our bystander participants, we adopted the neutral wording technique by including a spectrum of viewpoints of other people [21, 85]. We pilot tested three different phrasings (describing the viewpoints of other people without any examples, describing the viewpoints with examples, and without describing any viewpoints) each with 60 participants for the condition ‘Front-Back FoV’. For the condition ‘viewpoints with examples’, we added the following text at the end of the description of the two questions we asked the participants (Q1 and Q3)– “*Although some people are comfortable sharing such information (e.g., since sighted people already have access to this information), some may not feel comfortable (e.g., because of privacy concerns). We are interested to know how you feel along this spectrum.*” In the condition with viewpoints, we used the same phrasing as above but didn’t



provide any examples. In the condition without viewpoints, we did not add any phrasing. To analyze the differences in comfort levels, we conducted an overall Kruskal-Wallis test between three phrasing conditions. We did not observe any significant differences among three phrasings ( $\chi^2 = 3.9901, p = 0.136 > 0.05$ ). We also conducted a Kruskal-Wallis test to observe the differences in the usefulness levels between the three phrasings. Here too, we did not observe any significant differences among the three phrasings ( $\chi^2 = 1.6134, p = 0.4463 > 0.05$ ). Therefore, for the main study we only considered the condition – describing the viewpoints of other people with no example.

**3.7.2 Bot detection.** In the bystander survey, we encountered a large number of automated (‘bot’) responses in the initial stages of the study. We followed the following recruitment criteria – ‘workers’ of MTurk with an approval rating of at least 95% on at least 1,000 completed HITs, criteria that many prior studies followed [69, 73]. For the open-ended questions in the survey, we limited the responses to be at least 200 characters. While analyzing data from the qualitative responses, we observed a large number of irrelevant answers from the participants. Two researchers individually coded the open-text responses following a top-down approach. The researchers coded the data considering three themes – bot responses, not-bot responses, and not sure responses. Cohen’s Kappa was calculated among the two raters and an acceptable average pairwise Cohen’s Kappa score of 0.8 was achieved after the coding. All disputes were discussed after the coding and among the 318 responses, 211 (66.35%) responses were identified as bot responses. They identified 90 (28.3%) responses as not-bot responses and 17 (5.35%) responses as not sure. We compensated the respondents whose responses were identified as not sure. We did not include the data collected from the pilot study in the main analysis.

Therefore, when further recruiting participants for the main study, we updated our recruitment criteria with ‘workers’ of MTurk with an approval rating of at least 98% on at least 1,000 completed HITs to avoid bot responses (details added in Section 3.5). To ensure high quality data, we also added a captcha at the beginning of the survey. We enabled the default protection mechanisms of Qualtrics to avoid multiple responses – RelevantID (which assesses respondent metadata such as location, operating system, and browser to determine the likelihood of duplicate responses), prevent multiple submissions by placing cookies on the browser, and bot detection that uses Google’s invisible reCaptcha technology [17]. Qualtrics provide several reserved embedded data which indicates the probability score of a response being bot or fraudulent. We discarded the responses if the scores were below or higher than the threshold value suggested by Qualtrics. Moreover, we added an attention check question – “*What answer do you get when you add the number six to the number two? Answer in one word*” as an image. All of our participants passed this attention check and we received zero bot responses after including all these features and all of our complete responses passed Qualtrics’s quality checks.

### 3.8 Quantitative data analysis

Our data do not meet the assumptions of parametric tests, such as normality and equal variance of errors. Hence, we used non-parametric versions for our statistical tests. We have two dependent variables (comfort and usefulness) and one independent variable (FoV). To analyze our data, we conducted an overall Wilcoxon rank sum test (for two groups, between subjects), and Friedman rank sum test (for multiple groups, within subjects) across all conditions to analyze differences in the measured variables among the conditions. For the Friedman rank sum test, we performed pairwise Wilcoxon signed rank tests as the post hoc test using Benjamini-Hochberg (BH) correction for multiple comparisons.

### 3.9 Power analysis

A power analysis was performed to estimate the sample size required to produce statistically significant findings. The analysis showed that 64 participants per condition would provide enough statistical power to detect 0.5 ('medium') sized effects ( $\alpha = 0.05$ ;  $1 - \beta = 0.80$ ).

### 3.10 Qualitative data analysis

Two researchers independently coded all free-text responses following a bottom-up approach. The researchers iteratively and redundantly coded subsets of the responses and met weekly to discuss conflicts. The subsets were a combination of the two FoV conditions ('Front' and 'Front-Back'). The researchers coded each response into one of the four reasons related to information sharing or accessing practices. Cohen's Kappa was calculated among the two raters for each subset, and disputes were discussed after coding a subset of qualitative data. After two rounds of redundant coding, an acceptable average pairwise Cohen's Kappa score of 0.8 or greater was achieved for each subset of the two conditions.

## 4 QUANTITATIVE FINDINGS

In this section, we present our quantitative findings based on our statistical analyses. We start our findings by reporting our participants' demographics. Next, we discuss the information needs and comfort levels of PVIs with receiving information about bystanders and how their preferences vary based on the field of view. Next, we present a comparison of comfort levels between PVIs and bystanders. Finally, we present the relative usefulness levels between PVIs and bystanders and how the preferences of bystanders vary based on the fields of view.

### 4.1 Demographics

Participant demographics for the two surveys are listed in Table 2. Among the visually impaired participants, 84 (65.6%) were totally blind, whereas 44 (34.4%) lived with different levels of visual impairments such as 'Completely blind in one eye, and partially sighted in other'. More than half of the participants, (81, 63.3%) were visually impaired since birth, whereas the rest became visually impaired afterward: 15 (15.6%) since childhood, 13 (10.2%) since early adulthood (18–40 years old), 10 (7.8%) since middle adulthood (41–60 years old) and one (0.8%) since late adulthood (61+ years old).

Visually impaired participants also reported their use and purpose of using various camera based assistive technologies. Some common assistive technologies used by the participants were Seeing AI (75%), BeMyEyes (68.7%), TapTapSee (66.4%), and KNFB reader (63.2%). Most participants (89%) reported using assistive technologies for more than a year, and more than half (62.5%) mentioned using these 'frequently'. The purpose of using assistive devices included reading documents (114, 89.1%), identifying objects (95, 74.2%), identifying colors (84, 65.6%), navigation (82, 64.1%), and to obtain information about other people (30, 23.4%). All of our bystander participants mentioned using computer and 111 of them (82%) use smartphones regularly.

### 4.2 Information needs and comfort levels of PVIs

For more meaningful comparisons, we categorized the visually available information into three types: 1) Visual attributes (age, height, weight, appearance, gender, and ethnicity); 2) Behavioral attributes (expression, gaze, available for conversation, and current activity); and 3) Distance.

Figure 1 shows the relationship between the usefulness of various types of information about bystanders and the comfort level of receiving that information as reported by PVI participants. To observe the relation between the necessity of the information and the comfort level of receiving the

	PVIs	Bystanders
<b>Gender</b>		
Female	88 (68.8%)	59 (43.4%)
Male	40 (31.2%)	77 (56.6%)
<b>Age</b>		
18-29	22 (17.2%)	42 (30.9%)
30-39	23 (17.9%)	65 (47.8%)
40-49	29 (22.7%)	18 (13.2%)
50-64	25 (19.5%)	9 (6.6%)
65	18 (14.1%)	2 (1.5%)
<b>Education</b>		
High school	11 (8.6%)	21 (15.6%)
Some college	40 (31.4%)	48 (35.6%)
Bachelors	32 (25%)	54 (40%)
Masters	30 (23.4%)	11 (8.1%)
Post-graduate	6 (4.6%)	1 (0.7%)
<b>Occupation</b>		
Employed full-time	39 (30.4%)	95 (69.9%)
Employed part-time	17 (13.3%)	20 (14.7%)
Unemployed looking for work	27 (21.1%)	5 (3.6%)
Unemployed not looking for work	11 (8.6%)	11 (8.1%)
Student	16 (12.5%)	3 (2.2%)
Retired	15 (11.7%)	5 (3.6%)

Table 2. Demographic information of participants.

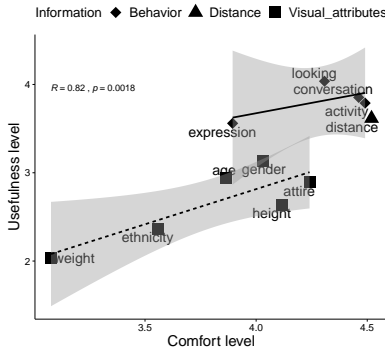


Fig. 1. Correlation between usefulness and comfort level of receiving information with regression lines and their confidence intervals (PVI).

information using assistive technologies, we conducted a Pearson’s correlation test and detected a significant positive correlation between comfort level and usefulness level of information ( $r = 0.82, t = 4.36, p = 0.00183$ ). Despite this high correlation, we do find examples of useful information that cause relative discomfort (e.g., expression) and some information that is generally less useful as we will see below.

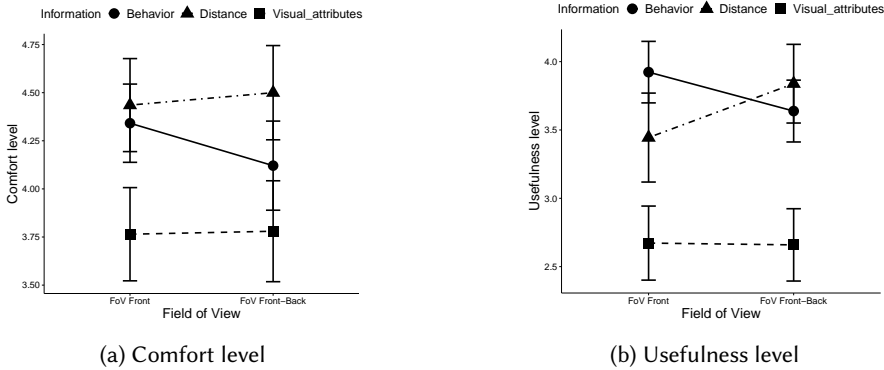


Fig. 2. Interaction between usefulness and comfort level for receiving information and FoVs (PVIs)

Participants reported that information about other people’s behaviors is most useful and knowing someone’s visual attributes is the least useful to them. (The section on Qualitative Findings sheds more light into participants’ responses.) We conducted an overall Friedman rank-sum test and detected at least one statistically significant difference ( $\chi^2 = 50.194, p < 0.00001$ ) between information needs of the participants. Next, we conducted pairwise Wilcoxon Signed-Rank tests with a BH correction to detect any significant differences between different attributes. For all comparisons, pairwise tests reveal significant differences except distance and behavior. From the analysis, we can observe that the difference in average usefulness of visual attributes ( $\mu = 2.67, \sigma = 1.06, 95\% \text{ CI } [2.5, 2.9]$ ) is much lower (Cohen’s  $d$ : 0.9) than the usefulness of behavioral information ( $\mu = 3.78, \sigma = 0.9, 95\% \text{ CI } [3.6, 3.9]$ ) ( $p = 2e^{-16}$ ) as well as (Cohen’s  $d$ : 0.7) distance ( $\mu = 3.64, \sigma = 1.22, 95\% \text{ CI } [3.4, 3.9]$ ) ( $p = 1.2e^{-13}$ ).

Overall, the comfort level of receiving information about bystanders is strongly associated with the necessity of the information to PVIs. PVIs also felt that receiving behavioral and distance information was much more important than knowing visual attributes. However, among the visual attributes weight and ethnicity were reported as least useful and PVIs were least comfortable getting these two information. In general, not wanting to know about visual attributes were related with ‘impropriety’ and stigma associated with that information as we will see in our qualitative findings.

### 4.3 Field of view preferences of PVIs

Next, we analyze the comfort levels and perceptions of usefulness for PVIs accessing various classes of information in the two fields of view (see Figures 2a and 2b).

We conducted Wilcoxon rank-sum tests to observe the interaction between different FoVs and the *comfort* level for each information category. We observed no significant differences in comfort level for each category across two FoVs for PVIs.

We also conducted Wilcoxon rank-sum tests to observe the interaction between different FoV conditions and the *usefulness* of each information category. We observed a significant change only for ‘behavior’ ( $\chi^2 = 2349, p = 0.04$ ), with PVI participants finding behavior somewhat more useful (Cohen’s  $d$ : 0.27) in the Front FoV condition ( $\mu = 3.92, \sigma = 0.89, 95\% \text{ CI } [3.7, 4.1]$ ) as compared to the Front-Back FoV ( $\mu = 3.63, \sigma = 0.89, 95\% \text{ CI } [3.4, 3.9]$ ).

Overall, we find that behavioral information is more useful to PVIs in the Front FoV compared to the Front-Back FoV (e.g., typically behavior cues are more important in face-to-face conversations

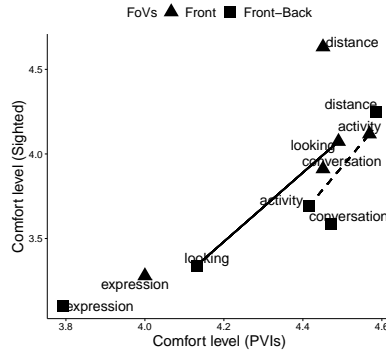


Fig. 3. Relation between comfort level of bystanders and PVIs

as we discuss in the qualitative findings). However, we note that for all the other information, PVIs find them to be similarly useful in both fields of view, and are comfortable in both situations. This suggests that PVIs are less concerned about stigma associated with Front-Back FoV; as we discuss in our qualitative findings, PVI participants mentioned it as ‘fair’ to receive information from an Front-Back FoV because sighted people can gather such information ‘with a simple turn of the head’ [PV125].

As we observe a lower necessity as well as comfort levels of receiving visual attributes reported by PVIs, we focus only on the behavioral and distance information in the following quantitative analysis. However, we dig deeper into these differences related to visual attributes in our qualitative analysis.

#### 4.4 PVI vs. bystander: Comfort and usefulness levels

Figure 3 illustrates the relation between the comfort levels of bystanders for providing various classes of information and PVIs as recipients of the information in two FoVs.

*Relative comfort levels.* We conducted a Wilcoxon rank-sum test to observe the interaction between the comfort levels of PVIs and bystanders for behavior and distance and observed statistically significant differences only for behavioral information ( $W = 94588, p = 2.2e^{-16}$ ). Among the behavioral information, our bystander participants reported being less comfortable (Cohen’s  $d$ : 0.5) in sharing information whether they are ‘looking’ at the PVIs ( $\mu = 3.71, \sigma = 1.32, 95\% \text{ CI } [3.5, 3.9]$ ) compared to the comfort level of PVIs for receiving that information ( $\mu = 4.3, \sigma = 1.05, 95\% \text{ CI } [4.1, 4.5]$ ) ( $p = 4.1e^{-05}$ ). Bystanders also reported more discomfort (Cohen’s  $d$ : 0.5) sharing their ‘activity’ with PVIs ( $\mu = 3.9, \sigma = 1.19, 95\% \text{ CI } [3.7, 4.1]$ ) compared to the comfort level of PVIs ( $\mu = 4.42, \sigma = 0.96, 95\% \text{ CI } [4.2, 4.6]$ ) ( $p = 2.7e^{-05}$ ).

Additionally, we also found that – opposite to PVI comfort levels as reported in Section 4.2 – bystanders were *less* comfortable sharing their behaviors compared to their visual attributes. For the bystander participants, to observe the difference in comfort level, we conducted overall Friedman rank-sum tests between different information categories. We detected at least one statistically significant difference exists between their information sharing preferences between different attributes ( $\chi^2 = 101.5, p = 2.2e^{-16}$ ). Next, we conducted pairwise Wilcoxon Signed-Rank tests with a BH correction to detect any significant differences between various information and observed significant differences for all pairs. Interestingly, bystanders reported slightly lower comfort (Cohen’s  $d$ : 0.17) for sharing information related to their behaviors ( $\mu = 3.63, \sigma = 1.08, 95\% \text{ CI } [3.5, 3.8]$ ) as compared to information about their visual attributes ( $\mu = 3.85, \sigma = 1.03, 95\% \text{ CI } [3.7, 4.0]$ )

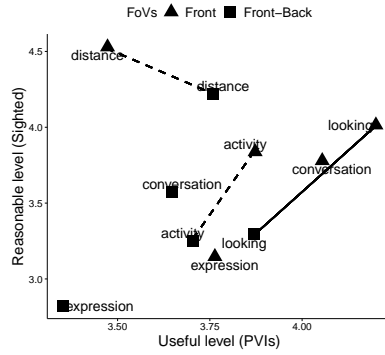


Fig. 4. Relation between usefulness and reasonableness level of PVI and bystanders

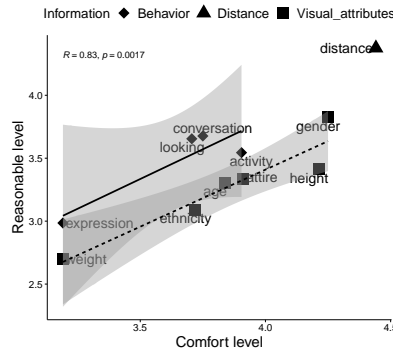


Fig. 5. Correlation between reasonable level and comfort level of sharing information with regression lines and their confidence intervals (bystanders).

( $p = 0.0012$ ) and much more in the case of distance ( $\mu = 4.44, \sigma = 0.98, 95\% \text{ CI } [4.3, 4.6]$ ) ( $p = 4.5e^{-14}$ , Cohen's  $d : 0.64$ ). Bystanders also reported a higher comfort level for distance as opposed to visual attributes ( $p = 4.4e^{-11}$ , Cohen's  $d : 0.5$ ).

**Relative usefulness level.** We conducted a Wilcoxon rank-sum test to observe the interaction between the usefulness levels of behavioral and distance information for PVI and how reasonable bystanders feel it is for PVI to receive that information. We observed statistically significant differences for both behavioral information ( $W = 120233, p = 0.0009857$ ) and distance ( $W = 11463, p = 2.256e^{-07}$ ) information (Figure 4). Our bystander participants considered distance information significantly more reasonable ( $\mu = 4.38, \sigma = 0.91, 95\% \text{ CI } [4.2, 4.5]$ ) compared to its usefulness ( $\mu = 3.64, \sigma = 1.22, 95\% \text{ CI } [3.4, 3.9]$ ) rated by PVI. Among the behavioral information, our bystander participants considered expression as the least reasonable information to share with PVI (Cohen's  $d : 0.4$ ) ( $\mu = 2.9, \sigma = 1.42, 95\% \text{ CI } [2.7, 3.2]$ ) compared to the usefulness level of that information to PVI ( $\mu = 3.5, \sigma = 1.18, 95\% \text{ CI } [3.3, 3.7]$ ) ( $p = 0.002952$ ). We did not observe any statistically significant differences between other behavioral information.

Similar to the PVI survey, in the bystander survey, we observed a significant positive correlation between the comfort level of sharing information and how reasonable the bystanders feel it would be for PVI to receive that information (Figure 5). We conducted Pearson's correlation test and detected a significant positive correlation ( $r = 0.83, t = 4.4199, p = 0.0017$ ). However, despite

this high correlation, we do find examples of information that bystanders find reasonable but yet feel relatively uncomfortable (e.g., behavioral information). We conducted overall Friedman rank-sum tests between different information categories to observe the differences in reasonableness levels. We detected at least one statistically significant difference exists between how reasonable they consider it to share different information categories with PVI ( $\chi^2 = 99.534, p = 2.2e^{-16}$ ). Next, we conducted pairwise Wilcoxon Signed-Rank tests with a BH correction to detect any significant differences between various information and observed significant differences for all pairs. Interestingly despite the correlation, bystanders find it slightly more reasonable (Cohen's  $d$  : 0.17) for PVI to receive behavioral information ( $\mu = 3.47, \sigma = 1.13, 95\% \text{ CI } [3.3, 3.7]$ ) compared to the information about visual attributes ( $\mu = 3.27, \sigma = 1.13, 95\% \text{ CI } [3.1, 3.5]$ ) ( $p = 0.0045$ ) which is opposite to their comfort level. However, similar to the comfort level, the reasonableness for distance ( $\mu = 4.38, \sigma = 0.91, 95\% \text{ CI } [4.2, 4.5]$ ) rated by the bystanders was much higher compared to visual attributes ( $p = 3.2e^{-16}$ , Cohen's  $d$  : 1.07) and behavioral information ( $p = 6.3e^{-16}$ , Cohen's  $d$  : 0.89).

*Field of view preferences.* Figure 3, however, also illustrates consistent bystander discomfort about sharing information in the Front-Back FoV compared to the Front FoV. We conducted Wilcoxon rank-sum tests to observe the interaction between different FoVs and comfort levels of PVI and bystanders for different information (behavioral and distance). We observed significant differences across the two FoV conditions for both bystanders and PVI for the information whether the bystander is 'looking' at PVI ( $W = 10434, p = 0.0002$ ) (solid line). For the 'activity' of the bystanders, the comfort level of bystanders were marginally significant ( $p = 0.055$ ) (dashed line). Thus in general, our bystander participants were somewhat less comfortable (Cohen's  $d$ : 0.3) in the Front-Back view condition relative to the Front view when sharing 'looking' and 'activity' information.

Figure 4 shows how bystanders consistently consider it less reasonable for PVI to receive information from a Front-Back FoV as opposed to a Front FoV. We conducted Wilcoxon rank-sum tests to observe the interaction between different FoVs and the usefulness of behavioral and distance information to PVI and the reasonableness indicated by bystanders. We observed significant differences across the two FoV conditions for both bystanders and PVI for the information whether the bystander is 'looking' at PVI ( $W = 10648, p = 0.0004264$ ) (solid line). For the 'activity' ( $p = 0.02663$ ) and 'distance' ( $p = 0.03046$ ) information, the reasonableness rating differences by bystanders was statistically significant between the two FoVs (dashed line).

Overall, we see that bystanders were comfortable with sharing their distance information and also consider it as reasonable information for PVI to receive. However, while behavioral information is most useful to PVI – and they feel comfortable seeking it – bystanders are relatively uncomfortable sharing information about their behaviors. However, they consider behavioral information as reasonable information for PVI in social situations. There is also a small overall effect of bystanders being less comfortable and consider it less reasonable sharing their information in the Front-Back FoV. However, we observed a larger effect related to 'looking' and 'activity' in a Front-Back FoV as reported by the bystander participants.

#### 4.5 Additional factors

*Gender and information preference.* We found no significant differences between PVI participants who identified as male and female and omit further details. For bystanders, the only statistically significant difference we found was for sharing of visual attributes ( $W = 1353, p = 0.00825$ ). Female participants were slightly more hesitant (Cohen's  $d$ : 0.1) to share visual attributes ( $\mu = 3.65, \sigma = 1.02, 95\% \text{ CI } [3.4, 3.9]$ ) with PVI than male participants ( $\mu = 4.0, \sigma = 1.0, 95\% \text{ CI } [3.8, 4.3]$ ). However, as we observed earlier, visual attributes were deemed less useful by PVI and may not be needed in general.

*Impact of level of visual impairments.* We provided an open-text option to collect the level of visual impairments of the participants in the PVI survey. For our analysis, we combined the responses into two groups: ‘totally blind’ and ‘low vision’. We conducted an overall Wilcoxon rank sum test ( $W = 187210, p = 0.01208$ ), which shows that participants with low vision were slightly *less* (Cohen’s  $d: 0.1$ ) comfortable ( $\mu = 3.94, \sigma = 1.18, 95\% \text{ CI } [3.8, 4.0]$ ) than the totally blind participants ( $\mu = 4.1, \sigma = 1.21, 95\% \text{ CI } [4.0, 4.2]$ ) about receiving information about bystanders.

We conducted an overall Wilcoxon rank sum test to explore the effect of level of visual impairments on the perception of usefulness of knowing information about other people. The result shows no significant differences ( $p = 0.92$ ). We performed another overall Wilcoxon rank sum test to observe differences between participants who have been visually impaired since birth versus participants who became visually impaired later in their lives. We found no statistically significant differences for both comfort ( $p = 0.45$ ) and usefulness ( $p = 0.85$ ) levels between the groups.

Overall, we observed that participants who have low vision are slightly less comfortable in receiving information compared to the totally blind participants. It could be that low vision participants feel less deserving of such information compared to totally blind participants, but this difference deserves further exploration.

#### 4.6 Summary of quantitative findings

Overall, in our quantitative analysis, we observed a strong positive correlation between the information needs and comfort levels of PVI in receiving information of bystanders. Our findings indicate that people with visual impairments feel much less necessity and are more hesitant to receive information related to visual attributes compared to behavioral information and distance, which they feel are much more useful. Although we observed no significant differences in *comfort* level between the two FoVs by the PVIs, our findings indicate that bystanders are somewhat less comfortable when sharing behavioral information, especially in a Front-Back FoV. Although PVIs reported similar *usefulness* between two FoVs for visual attributes and distance, our findings indicate that PVIs consider behavior information to be somewhat more useful in a Front FoV as compared to the Front-Back FoV. Despite considering behavioral information more reasonable to share with PVIs compared to visual attributes, our bystander participants reported lower comfort level for sharing behavioral information as opposed to visual attributes. Our findings also indicate that people with low vision are slightly less comfortable in receiving information about bystanders compared to people who are totally blind. To understand the reasons for such preferences, we will discuss our qualitative findings in the following section.

### 5 QUALITATIVE FINDINGS

We will now discuss qualitative findings from our surveys, which shed light on the reasons behind our quantitative findings as expressed by both PVIs and bystander participants. We observed that the information needs and the comfort levels of receiving information by PVIs and the information sharing preferences of bystander participants differ based on various factors. Next, we discuss our findings related to concerns about ‘misrepresentation’, ‘impropriety’, and ‘fairness’, which are important facts that should be considered in the design of camera based assistive technologies. Finally, we discuss the additional visually available information needs of PVIs.

#### 5.1 Misrepresentation of information

Representation of self [62] is an important aspect of one’s daily privacy management, where people navigate different social spaces with well-crafted and evolving personas. We find several concerns of PVIs related to potential inaccuracies in automated recognition and how it might affect the



presentation of bystanders, as well as their own self-presentation, e.g., by behaving inappropriately on false information.

Several visually impaired participants (N=24) expressed their concerns over the quality and accuracy of the data received by the assistive glasses. In particular, they were worried about being embarrassed if they would act on inaccurate information.

*“If the percentage is high that the camera information is incorrect, I would be more likely to be embarrassed by trusting that information. The more likely I am to be embarrassed, the less comfortable I am in receiving the information.”* [PV37]

Participants shared their personal experience when assistive devices fail to provide accurate information and that make them skeptical about the functionality of such devices.

*“I’ve had AI tell me I look anywhere from 16 to 45 (I’m 21), so I question its accuracy. It would be incredibly embarrassing to be told someone looks to be a 25 year old man and turns out to be a 32 year old woman, and I act according to the information provided. I personally wouldn’t, as I know that AI can be wrong, but I can imagine situations arising where someone does trust it and ends up rather embarrassed.”* [PV32]

However, PVIs shared higher concerns about the accuracy of subjective and socially biased information such as gender and ethnicity. They also reported concerns regarding the fairness of algorithms in determining such information.

*“Information that requires subjective moral judgement can not be provided without bias in the algorithms to determine confidence. Providing information on gender which is not binary would likely to fail a majority of the time since algorithms would be focusing on physical attributes to determine an output.”* [PV88]

One participant gave example scenarios that could occur due to the misrepresentation caused by assistive technologies.

*“I’d be less comfortable with being told a person’s weight and gender because the algorithm’s likelihood of being accurate varies, which means I may move too close to a person if he/she is larger than expected. Even more humiliating would be to talk to a person using a pronoun they’re uncomfortable with as a result of assuming the algorithm was accurate gender-wise. For example, someone who is trans may be more difficult to identify if they are currently transitioning.”* [PV26]

Similar to visually impaired participants, bystander participants also shared concerns about being misrepresented by assistive devices. They were worried about sharing subjective information such as gender, ethnicity, and their emotional state for which the possibility of making an error was perceived as higher. They also reported they would feel embarrassed in situations when the information provided about them was incorrect.

*“I’m uncomfortable with the gender, cause I’m trans and the glasses would get it wrong at some point, which would give people more reasons to misgender me.”* [PB17]

*“I would not want it to ‘guess’ my weight or age. It would be embarrassing if guessed too high.”* [PB38]

Bystander participants also reported that their impressions might be affected in front of the PVIs if the glasses misrepresent them.

*“It would make me feel bad if the AI messed up and told them I was 400 pounds when I’m 200 pounds. Or if the AI said this person feels very sad even though I was happy. That makes me uncomfortable and might affect my overall first impressions of the person wearing the glasses as well as their own impression of me.”* [PB80]

Some bystander participants questioned the capability of AI in determining information correctly that is difficult for sighted people to determine as well.

*“In terms of mood, I am often mischaracterized as being angry or sad by people with no visual impairments. If real human beings can’t accurately gauge my mood by my facial expression, AI would probably be far more inaccurate.”* [PB33]

Overall, both PVI and bystanders expressed their shared concerns about being misrepresented by assistive glasses, which could lead to embarrassment for both groups. Their main concerns related to both inaccurate assessments of visual features, as well as subjective and behavioral information where the assistive systems are often likely to fail.

## 5.2 Impropriety vs social stigma

People with visual impairments are concerned about sighted people’s reactions towards them when they use assistive glasses. Shinohara et al. observed the stigma associated with assistive devices and how it affects the usage of such devices among people with disabilities [119]. Our participants reported similar stigma and how they are concerned about the reaction of people around them.

*“I would feel like a robot and I am more worried about how people look at me”* [PV86]

Some participants were unwilling to receive information from Front-Back FoV as sighted people can not see behind them. One participant compared receiving information from Front-Back FoV as having ‘superpowers’.

*“I don’t want anybody thinking I have eyes in the back of my head, or superpowers, really!”* [PV103]

PVIs reported being uncomfortable receiving gender information because of the social stigma associated with it.

*“I think the reason I am not emotionally on board is because of the stigma attached to it. It’s already considered negative to assume a person’s gender upon meeting them, and here I’d have AI doing it for me.”* [PV27]

However, beyond not wanting information because of concerns about being stigmatized, we found several examples of PVI’s wanting to maintain ‘propriety’, i.e., privacy decisions that *they* consider appropriate and fitting for society. Several of our participants were concerned about the appropriateness of receiving information of other people through assistive glasses. PVI’s did not want to receive information they considered as improper, where they felt they would be violating the privacy of bystanders. Reilly et al. similarly observed ‘propriety’ concerns among the participants regarding tracking the location of other people [111].

According to one participant obtaining information about someone’s weight was a clear “violation of privacy” and another said it was “impolite.”

*“I feel it is an invasion of privacy to know approximately how much someone weighs.”* [PV56]

*“I am not comfortable knowing someone’s weight as this isn’t discussed in polite society.”* [PV85]

Some visually impaired participants preferred not to receive certain information to avoid being judgmental towards bystanders. They were especially uncomfortable receiving information such as someone’s ethnicity, gender, or weight, which could then implicitly bias their attitudes.

*“I might fall into traps of judging people by their appearance just as sometimes sighted people do particularly about ethnicity, weight and gender identity/expression.”* [PV48]

One participant characterized blindness as a ‘*blessing*’ as it helps him avoid being judgmental. Some participants felt awkward receiving ‘too much information’ about people.

*“I don’t want to assume things about people and pass judgment on them. This is the blessing of the curse of blindness.”* [PV68]

Bystander participants, too, were mostly uncomfortable with sensitive information such as gender, ethnicity, and weight. They were worried that PVIs may become judgmental after receiving such information. Some bystander participants considered it as ‘inappropriate’ to share such touchy information.

*“Some information, like my weight or ethnicity might play to people’s prejudices or predispose the person to responding to me in a specific way before we’ve really interacted. Because they can’t see me well, they may make judgments about me.”* [PB18]

*“As a black man its gets pretty annoying having to deal with the issue of skin color in America and I do not know how that visually impaired person will react. I am somewhat against them announcing my weight as it’s something I am personally trying to get under control and would feel embarrassed if it was announced in a social gathering.”* [PB14]

Bystander participants also shared concerns about being judged based on their appearance or weight before interacting with the visually impaired person.

*“I feel like that it would be very judgemental, and I’m not ok with someone judging me based on my appearance rather than trying to get to know me for me.”* [PB126]

*“I believe that certain information (i.e. if I am looking at the impaired person, the distance between us) is more appropriate for a computer to read off. Other assumptions, such as my weight, or what my mood is, could be too personal for a computer to read into. Some info should be regarded with privacy.”* [PB04]

Overall, PVIs expressed a strong sentiment of ‘impropriety’ about receiving certain kinds of information about bystanders. They considered it to be an invasion of privacy to get information about attributes such as weight, age, ethnicity, and race, and wanted to avoid situations that might cause them to be implicitly biased by such information. Bystanders too shared these concerns, and thus we find agreement on certain attributes being ‘improper’ beyond issues of stigma imposed by bystanders.

### 5.3 Towards achieving fairness

Although previous work indicated that bystanders were uncomfortable with PVIs receiving information from a Front-Back FoV [21], recall that we found the PVIs do *not* consider this unfair in general. Our qualitative findings shed light on the preferences of PVIs.

Several participants with visual impairments (N=25) expressed their desire to achieve fairness by receiving information from a ‘Front-Back’ FoV along with the ‘Front’ FoV. Our participants felt that sighted people have the privilege of getting visual cues just by looking at others or a ‘simple turn of the head.’ For the Front FoV, one participant felt it was ‘only fair’ to receive such information since a sighted person in front had the same information about them:

*“I am comfortable with getting as much information about the person in front of me because it is only fair. They can see me and they can feel free to make any judgments about me so why shouldn’t I? It is only fair to both of us that I should be able to get nearly as much visual information about them, they will still get more about me since they are not depending on artificial intelligence for that information.”* [PV7]

Participants, however, also shared their comfort in getting information from a Front-Back FoV:

*“People who can see would be able to obtain this information by turning around and looking at people behind them, so I cannot see anything wrong with me obtaining this information.”* [PV117]

*“I am extremely comfortable receiving objective information that anyone with vision could find out with a simple turn of the head or movement of the eyes.”* [PV125]

As with our quantitative findings, we observed a higher importance of receiving distance information in a Front-Back FoV to maintain one’s physical safety.

*“The distance of someone behind me could be helpful, especially if I am feeling watched or followed.”* [PV112]

Almost a third of our bystander participants (N=45) shared a positive attitude towards sharing visually available information with PVIs. Although several bystander participants expressed discomfort with a Front-Back FoV (we omit these quotes since they are in line with previous findings [21]), some bystander participants also reported being comfortable in providing ‘equity’ to PVIs by sharing information when the PVIs are facing away from them.

*“Even though the person with the glasses isn’t turned in my direction, everyone else at the party is already seeing these things. I think it’s very reasonable for the visually impaired person to also be able to gather this kind of data. It only seems fair.”* [PB75]

Overall, PVIs considered it as ‘fair’ to receive information from both FoVs because they reasoned sighted people could get such information easily, and with a simple turn of the head if needed. However, as with previous work, we observed some bystander concerns with making information available from a Front-Back FoV.

#### 5.4 Behavioral information is more important

In our quantitative findings, we found that PVIs gave lower importance to some demographic information and higher importance to behavioral information. PVI participants felt that information that might change during a conversation was more valuable compared to static demographic information during their interactions.

*“I don’t feel the need for information about general appearance. It is good to know that someone is looking at me to decide whether to speak to them, but details of clothing, weight, or age aren’t important to me.”* [PV16]

*“Some characteristics about a person like their height or weight affect my interaction with them less than other details because they are fixed traits that will not change in the short time I’m around them. Other details, however, are more fluid and change like mood or what they are doing. For instance, a person’s emotional state can change from one moment to the next depending on our interaction.”* [PV26]

Echoing the PVI participants, our bystander participants also felt that knowing some behavioral information would make the PVIs more comfortable with their surroundings and might help them in deciding how to approach and proceed with certain social situations.

*“I think the glasses telling them whether someone is looking at them and the distance between them are the most reasonable things to ask for. While it’s very helpful for a vision impaired person to know what the other person is feeling, I wonder how accurate it would be and if it wouldn’t be easier to figure that out other than visually. The glasses telling the wearer what the other person looks like isn’t as important as the other options.”* [PB9]

However, we found, on the other hand, bystander participants were more hesitant in sharing behavioral information compared to visual attributes, which are ‘readily obvious’ to sighted people. For example, information about emotional state or activity were considered off-limits.

*“Once we get into what I’m doing and my emotional state it becomes more an invasion of privacy. I do not want people to know what I’m doing. That is an invasion. I am not a very social person as it is and I feel like this would make it worse for me.”* [PB74]

*“I am perfectly fine with non-identifying information like age, gender, height. This is something people with normal vision are able to see. I am not comfortable with them knowing what I am doing. That is private information and none of their business.”* [PB82]

Overall, PVIs and bystanders imposed more importance on receiving behavioral information about bystanders compared to the visual attributes. However, bystanders expressed less comfort in sharing behavioral information and felt it was a violation of their privacy to share behavioral information.

### 5.5 Additional information needs of PVIs

Apart from the visually available information we listed in our survey, our visually impaired participants also shared additional information needs in an open text question (Question VQ5 in Section 3.3). Some participants expressed their desire to know whether the other person has any disability or has visual impairments. They also wanted to learn whether the person is using any mobility aid (e.g., wheelchair, cane, or service dog).

*“Whether they use a particular mobility aid such as a wheelchair, have a service dog with them.”* [PV110]

Participants were also interested in knowing the identity of the person, e.g., using the smart glasses to read name tags at conferences and political gatherings, sometimes to avoid certain people:

*“If they are wearing a name badge it would be helpful in finding people or maybe avoiding others.”* [PV90]

*“Recognizing text on name tags would be helpful at a conference.”* [PV87]

Interestingly, several participants wanted to know whether the bystander has something in their hand. Knowing that would provide them the context of whether the person is available to help.

*“Other useful aspects to know about those at a social gathering include whether or not they are holding anything in their hands because this would give me a better idea of if they are available to help if I need it.”* [PV45]

As for appearance information, we considered only attire in this study. However, our participants expressed the desire to know more about the person’s appearance or accessories such as hairstyle, jewelry, tattoos, and wedding rings. They were also interested to be informed about the particular activity of the bystanders. For example, whether someone is trying to distract their guide dog.

*“I would like to be aware if someone is making eye contact with my guide dog or attempting to interact with him and distract his attention from his duties. I would want to know if they are trying to feed or pet him.”* [PV34]

Overall, our visually impaired participants considered several additional types of information that might be useful, such as associating names with faces, whether the bystander has any disability, and details about their appearance and activity.

## 6 DISCUSSION

Although assistive technologies can be helpful to people with visual impairments (PVIs) when engaging in social interactions, our participants reported several *shared concerns* related to the fallibility and invasiveness of such devices and disagreed on issues related to fairness. Prior work has focused on the biases present in current AI-based systems and the ethical issues emerging from identifying subjective information that could misrepresent different marginalized populations.

Here, we identify implications for design based on our findings that could increase the acceptability and utility of camera based assistive technologies to both PVI and bystanders while considering these ethical issues. We first start by summarizing our key findings.

## 6.1 Key findings

**6.1.1 Fairness and equity.** Our findings suggest that PVI are equally comfortable in receiving information from both Front and Front-Back fields of view (FoVs). PVI considered it ‘fair’ to receive information from a Front-Back FoV (i.e., not just from directly in front of where they are facing) because sighted people also have easy access to such information, e.g., “with a simple turn of the head” (P125). However, we also observed hesitation from some PVI in receiving information from a Front-Back FoV because of the social stigma associated with it. Additionally, bystanders generally felt less comfortable (e.g., an ‘invasion’ of their privacy) if information is provided to PVI when they are not directly facing the person.

In the context of information needs, PVI consider *behavioral* attributes (e.g., gaze, expressions, activity) as most useful for social interaction. While such preferences have also been identified in previous work [19, 83, 86], our study confirms the preferences quantitatively and in the context of the preferences of bystanders. Surprisingly, bystanders considered behavioral cues through automated systems as a privacy invasion, and were least comfortable sharing this information. For example, they were worried about such information being taken out of context, e.g., where casual eye contact while one’s mind wanders might be misinterpreted (PB33).

Similar to our findings, Lee et al. also experienced hesitance from bystander participants in sharing facial expressions and head pose [86]. They also observed the visibility of the camera and awareness of the technology are associated with the acceptability of wearable devices by bystanders; the less visible the camera, the more negative they feel about being recorded. Given the misalignment, *more research is needed into how such systems can be designed to improve their acceptability to PVI and bystanders when information is provided from a Front-Back field of view and how to appropriately convey behavioral information about people without mischaracterizing their intentions.*

**6.1.2 Propriety concerns.** PVI expressed ‘propriety’ concerns about accessing information about bystanders and described it as a violation of bystanders’ privacy when receiving information about ‘personal’ attribute information (such as weight and gender). Prior works investigate how privacy norms allow people to practice ‘tactful/civil inattention’ to respect the privacy of others [29, 62, 71]. We observed similar behavior where our participants were worried about becoming judgmental and enacting implicit biases towards bystanders by receiving such information, and preferred to ignore such information. Bystanders also expressed concerns about the possibility of PVI being judgmental by receiving information about them before knowing them in person. They were concerned, in particular, about being judged by their physical appearance upon receiving such information by PVI. Some considered it as the invasion of their privacy when it comes to sharing their behavioral and other sensitive information (e.g., emotion or age). *Our findings suggest that future assistive devices should also focus on the ‘propriety’ concerns of PVI and avoid characterizing bystanders in ways that could lead to judgmental attitudes that PVI would also like to avoid.*

**6.1.3 Fallibility of AI: Misrepresentation and accuracy.** Participants from both surveys were concerned about the accuracy of AI-based assistive devices and the potential to misrepresent information about bystanders to PVI. Both parties were concerned about embarrassing situations that might be caused through inaccurate information and acting upon those in social interactions. Regarding accuracy, participants were most concerned about inferring subjective information such as gender and ethnicity. They also described emotions as a complex expression that can be

often mischaracterized by other humans, let alone algorithms. Such concerns about the accuracy and misrepresentation by AI is also discussed in prior work [23, 28, 67, 77]. Akter et al. observed how PVI's often prefer professional agents or volunteer-based technologies for obtaining answers of higher quality as opposed to AI-based systems [23]. Prior studies also discussed how different marginalized populations experience similar misrepresentation by other humans [28, 34, 67]. Bennett et al. discussed how their non-binary and transgender participants were misgendered frequently and the races of their Black, Indigenous, Person of Color (BIPOC) participants were assumed inaccurately by other people [34]. They found that a majority of their non-binary and transgender participants were affected negatively from such misrepresentations. Moreover, Hamidi et al. found that automatic misgendering can be perceived as even more harmful than being misgendered by other people [67]. Similar to our findings, Andalibi and Buss found that emotion is not only complex but also individualized, and it is hard to define even by humans [28]. *It is thus imperative that designers of such devices should be careful about – or avoid – inferring subjective information about people and consider the negative effects of misrepresentation on end-users.*

## 6.2 Ethical considerations of detecting gender, race, and emotion

Our participants indicated concerns about how assistive technologies can inaccurately assess subjective and socially biased information and negatively impact them in social situations. Our participants focused on how the real world is full of biases and that AI is not any different. They also shared concerns that such systems can affect different marginalized groups by misrepresenting them because algorithms don't consider individual preferences while making decisions. Recent work has focused on these bias and fairness issues of AI and their effects on marginalized populations [28, 42, 55, 67, 68, 77, 97, 112, 116, 125]. The misclassification of race by automated technology can result in severe societal discrimination [5, 13, 42] and have real life consequences (e.g., the wrongful arrest of a person because of biased facial recognition systems [14] and failing to monitor pulse for people with darker skin by Apple watches [68]). Hamidi et al. emphasized how gender cannot be detected accurately through physical features (face, body, or voice) by either humans or digital algorithms [67]. Their participants shared privacy and safety concerns from automatic gender recognition systems and how these systems challenge their autonomy. They were worried that such systems might reinforce gender binaries, override user autonomy, and impose surveillance that undermines their privacy and safety. Prior works questioned the necessity and usefulness of gender recognition algorithms and discussed their real-life applications (such as targeted advertisements and limiting entry to bathrooms based on gender) that could negatively affect trans and non-binary identifying people [15, 42, 67, 68, 77]. They advocated to avoid implementing gender recognition applications based on facial analysis [77] and a campaign has been launched to ban such applications in the EU [15, 16]. However, in the context of assistive technologies for people with visual impairments gender or race related information could be useful in particular contexts as reflected by our findings and prior work [34, 86]. Moreover, to achieve fairness and equity, it can be argued that PVI's should be given access to information also available to the sighted people. *More research and dialogue are required to balance the need for automatic gender and race recognition systems for PVI's against the cost to the autonomy and privacy of marginalized groups in the context of assistive technologies. As we discuss below, potential solutions can focus on more objective characterizations and steer clear from subjective characterizations.*

Our bystander participants considered emotion detection as an 'invasion' of their privacy. Recent works also identified data about emotions and data with emotional implications as highly sensitive and personal [28, 112]. Roemmich and Andalibi observed that people feel skeptical towards the capability of automatic emotion recognition (ER)-enabled well-being interventions. They believe such systems cannot support in the way humans can, and expressed concerns about the potential

harms caused by the systems – re-traumatization, inappropriate surveillance, and inaccurate predictions. A large body of work emphasized on the potential of ER as well-being interventions to cause harm to vulnerable populations (e.g., mental health patients) and raised concerns about ER’s algorithmic fairness and transparency [30, 32, 35, 44, 60, 66]. Racial and ethnic minority groups can also face negative consequences while assessing mental health states using automatic emotion recognition [38, 123]. People can also lose their autonomy from automatic emotion recognition in social media [28]. However, from our PVI participants we learnt that emotion is important information for them to decide whether to approach a person or not. *Therefore, we argue that emotion detection warrants explicit attention and further dialog, because we observed a mismatch in the information needs of PVIs and the sharing preferences of bystanders.*

### 6.3 Design implications and future directions for camera based assistive technologies

**6.3.1 Information needs are context dependent.** Our findings imply that people with visual impairments find certain visual attributes (e.g., gender, ethnicity, attire) less useful in social gatherings. However, such information might be useful in other situations or contexts. For example, gender could be a useful information in a dating scenario, whereas information about people’s appearance (e.g., professional attire) might be useful in conference or professional scenarios. Prior studies identify six scenarios (such as encountering unknown people, when seeking to ‘read a room’ and find community) when people with visual impairments require additional appearance descriptions [34]. The information needs and sharing preferences can also depend on the audiences they are interacting with. They found that people with visual impairments provide additional information about their appearance in disability-centered events compared to social media [34]. They also report that the self-disclosure of race, gender and disabilities of people with visual impairments also vary based on the known audience vs. public posts in the context of social media. Akter et al. observed how the information disclosure practices of PVIs vary depending on the audiences in the context of photo sharing with assistive technologies [25]. Moreover, prior studies identified the influence of cultural background on people’s privacy decisions [33, 91, 126, 130]. Wang et al. found that US people are more privacy concerned compared to Chinese and Indians [126]. Therefore, it would be useful to explore how the information needs of PVIs vary across cultures. *Therefore, more focus is needed to understand how the information needs of people with visual impairments can vary based on different contexts, cultures, and audiences.*

**6.3.2 Setting a standard for AI-generated descriptions.** From our findings, we observed hesitation from our participants with visual impairments about receiving certain types of subjective and socially biased information because of the potential to misrepresent bystanders. One of our PVI participants stated that they would feel more comfortable if a more general description (e.g., ‘average’ vs. ‘below average’) is given to describe someone’s weight instead of assigning an actual weight. Bystanders also raised concerns about giving precise or specific numbers (such as one’s weight) that sighted people cannot perceive easily and described it as ‘mortifying’. To increase accessibility and avoid being misrepresented, there is a trend to self-describe oneself in social gatherings and conferences. People share their age, gender, attire, background, and sometimes even race or skin color. Therefore, future systems could learn from the self-disclosure preferences of people and incorporate these in the AI-generated descriptions by assistive technologies to avoid potential misrepresentations. For example, in a controlled environment such as a conference or a meeting room, people could wear badges with their names and preferred pronouns, which the AI-based system can detect instead of relying on facial recognition. Such approaches could help avoid potential misgendering and the negative consequences associated with it. However, more research is needed to understand how to translate such design considerations in more unconstrained



environments, such as in public settings. Bennett et al. explored how people with visual impairments describe their appearance in image descriptions [34]. They advocate using language that focuses on visual details (e.g., skin tone) rather than presuming one's identity or other higher level inferences (e.g., race labels). For example, a description of clothing, accessories, and hairstyle can help to avoid gender assumptions. However, such language preferences can vary based on personal preference and context. *Therefore, future research should explore how such systems should use appropriate terminology to describe appearance and other visual information about people more objectively, leaving further interpretation to the individual users of the assistive devices.*

**6.3.3 Techniques to increase social acceptability of assistive systems.** Prior work has found that people's perceptions change towards a technology with repeated exposure [50]. Profita et al. reported that wearable devices have more social acceptability if it visually indicates that the device is being used for assistive purposes [107]. Grayson et al. suggested using different light indicators to alert bystanders of the type of information the system is recording [64]. We also observed similar ideas from our visually impaired participants, who felt more comfortable receiving information if the camera were visible to sighted bystanders, e.g., "as the camera is visible to others, I would feel comfortable getting the information as there's no deception going on here (PV73)". It would be useful to study ways in which social attitudes can be changed to get bystanders to understand the perspective of PVI and improve their willingness to provide information from a Front-Back FoV. Such attitudes could be influenced through design, e.g., with the use of indicators to inform bystanders about the types of information it is conveying (e.g., demographic vs. behavioral), where the information is being analyzed (e.g., locally or in the cloud), and the purpose for such collection [107]. Bennett et al. reported that PVI feel that if possible the image describers should discuss with the photographed person or authentic sources before describing their appearances to avoid assumptions. Our PVI participants also felt the necessity of including the consent and preferences of bystanders before inferring their information. *Therefore, more exploration is needed to understand how to involve both PVI and bystanders in the decision making process to share information about bystanders to improve the social acceptability of camera based assistive systems.*

**6.3.4 Require propriety policies.** Although receiving some information may be stigmatized by bystanders, PVI do consider some types of information as 'inappropriate'. Reilly et al. observed 'propriety' concerns arising from accessing location information of others and suggested the use of 'propriety policies' (e.g., a supervisor may want to view an employee's location *unless* the employee is at lunch or is at home, regarding the latter as an overreach) [111]. Assistive technologies could allow PVI to specify similar propriety policies about what they consider as inappropriate or 'too much information'. Thus, *improving the social acceptability of such devices requires not only work on removing associated stigma from the perspective of bystanders but approaches that don't make PVI feel like privacy violators from their own perspective.*

**6.3.5 Convey confidence information and include feedback from PVI.** Macleod et al. found that the trust of PVI on automatically generated captions is highly correlated with the confidence reported by the algorithm [93]. They recommended to phrase the automatically generated captions in a way that reinforces the possibility of the inaccurate caption ('negative framing'). In that way, the users of such devices can be aware of, and account for, the fallibility of such technology even if the algorithm may be 'confident' in its inference. Prior works observed that different audiovisual prosodic cues (such as intonation and fillers) contribute to the perception of confidence in the answers given by people [53]. Assistive technologies should incorporate such cues to convey confidence (or, more importantly, the lack thereof) to PVI, and more research is needed in this direction. The system can also introduce feedback from the end-users (e.g., whether they are satisfied or not) and provide

more information if required by the user to improve missing or low-quality answers [98]. Multiple captions indicating their confidence levels can also help PVIIs to have a better understanding or improved judgment about the description provided by the assistive devices [98].

*6.3.6 Algorithmic accountability, transparency, and explainability for assistive technologies.* Prior studies found that user's trust is related to the fairness, transparency, accountability and explainability of the algorithms [27, 43, 51, 88, 89, 118]. Algorithmic accountability is the assignment of responsibility for how algorithms are created, and their impacts and potential harms on society [43]. Algorithmic transparency helps to understand whether a system is fair and reliable [27]. However, transparency alone is not enough to gain users' trust or providing insights about the reasons of the decisions made by the algorithm [61]. Therefore, explainable AI aims to make an AI system's functioning or decisions easy to understand by people [31, 52, 61, 65]. Our PVI participants expressed a lack of trust towards assistive technologies and their capabilities to assess visually available information accurately. Our bystander participants were also concerned about the privacy and misuse of their data by such technologies. As a consequence, we observed stigma and the inclination to limit the use of assistive technologies by our PVI participants. Therefore, we identify as important, the dimensions of algorithmic accountability, transparency, and explainability for assistive technologies to avoid any potential harm to their users and gain users' trust. Moreover, to achieve fairness and to avoid biased responses, future assistive systems should include people with disabilities in application design and development and should gather training data from them. Research should focus more on representing marginalized groups and outliers to reduce biases and consider the concerns perceived by people with disabilities as well as bystanders.

## 7 LIMITATIONS AND FUTURE WORK

Our findings may not generalize to situations beyond the context of social interactions in public places. For example, in a workplace, where privacy expectations and concerns may be different and where there may be publicly available information (e.g., color coded badges with names of people on them) that is easy for sighted people to access, the privacy and propriety concerns may be very different. Prior works explored the information disclosure preferences of PVIIs in private, semi-private, and public scenarios [25]. Therefore, it would be worth exploring how the information need of PVIIs vary based on public vs. private scenarios. Our samples for the two surveys are gender imbalanced, and it is well-known that privacy concerns can differ with gender [25, 72, 117]. We found little or no significant gender differences in our quantitative analysis, however. Our participants were limited to one geographic area (the United States), and so our findings may not generalize to other regions. Researchers who study cross-cultural privacy concerns may be able to adopt the methods described in this paper to determine whether the information needs and privacy concerns of PVIIs and bystanders differ across cultures. Prior works found that U.S. MTurk workers were "younger and better educated," "put a higher value on anonymity and hiding information," and "had more privacy concerns than the larger U.S. public" [76, 113]. Similarly, we found that majority of our MTurk participants (78.7%) were typically in the age range of 18–40 years, and are more technology aware. Therefore, our findings may not generalize for all age groups. Future studies would need to triangulate our findings using other methods that reach technologically removed groups (such as the elderly and people in the Global South).

One concern could be the use of an online survey, which gives a verbal description of a more abstract technology rather than a paratyping [21] or a prototype-based [18, 86] study. These approaches have their merits but have the limitation that the specifics of the artifact may bias the participant and take the focus away from the actual information that is being accessed and shared. For instance, the camera could be part of a small clip-on device, or a spectacle, or a HoloLens, or a

smartphone camera in the wearer's pocket positioned to capture the scene. In each instance, the responses will be biased by the individual perceptions of such a device (such as a secret camera or obvious 'geek-tech'). We wanted to focus on the abstract information that is being shared and not on how it is gathered specifically. Indeed, survey-based methods have been widely adopted in the accessibility community [37, 49, 94] and are often encouraged, e.g., to avoid the difficulties people with disabilities may face traveling to the facility [106], and are more suitable as participants use their preferred screen readers in their own settings [36]. One concern is that bystanders too may not grasp the subtleties of how PVI's make use of information from such devices in a survey based study. Again, however, we wanted to capture general perceptions not tied to a particular prototype and based on their general perceptions of PVI's. However, it would be interesting to see whether a similar prototype-based in-person study or a face-to-face survey reflects the same or different results.

In this study, we considered only sighted people as bystander participants. However, the information sharing preferences may differ if the bystander is a person with visual impairments. Ahmed et al. [21] explored the information sharing preferences of sighted bystanders with PVI's vs. sighted recipients. They found that sighted bystanders are more willing to share information with PVI's compared to sighted wearers. However, it would be interesting to see to what degree bystanders with visual impairments are more (or less) willing to share information than sighted bystanders. Moreover, it would be also interesting to explore the information sharing preferences of PVI's with sighted wearers of AR glasses.

Ahmed et al. [21] observed that interaction before sharing information is important for bystanders; people tend to share more information after a conversation. Our findings also suggest that bystanders are concerned about being judged before having the opportunity for introduction with PVI's. Therefore, the relationship and interaction among the bystanders and PVI's should be explored at a larger scale.

Finally, a more subtle limitation, common to all such studies, is the implicit bias in all individuals based on their experience and exposure to technology in their everyday environment that cannot be captured or accounted for. For instance, a study about 'sending text messages while in a meeting' will elicit different responses based on the technology that is presumed by the respondent as the one being used: if the person is unfamiliar with touch-screen smartphone messaging but only is aware of standard keyboard based chat, their responses about the propriety of such actions will be very different. Our intention in this research is to bring out the core responses irrespective of the technology that may be used so that the technology that is to be created can address any concerns brought out by the study.

## 8 CONCLUSIONS

Our work explores the shared privacy and ethical concerns of people with visual impairments (PVI's) and bystanders in the context of camera based assistive devices. We surveyed both PVI's and sighted participants regarding their perspectives about different types of information collected in two field of view conditions. Although different fields of view highlighted some differences of opinion between PVI's and bystanders in terms of 'fairness' (bystanders were less comfortable with the Front-Back field of view), we found there was much they agreed on related to privacy. In the context of 'impropriety', we found PVI's are less comfortable accessing information such as age, weight, gender, and ethnicity about bystanders because they consider it 'improper' or 'impolite', and worry about their own implicit biases. Bystanders too, felt uncomfortable for similar reasons, demonstrating a shared concern between PVI's and bystanders about how much information is 'too much information'. In addition to impropriety, we found shared concerns about the 'misrepresentation' of bystanders through fallible artificial intelligence (AI). Both sets of participants had

significant concerns about not only the accuracy of information from AI based assistive solutions, but also the ethical implications of trying to algorithmically infer subjective social constructs (such as gender and ethnicity). Such AI based inferences could lead to misunderstandings and the misrepresentation of bystanders, leading to further marginalization of some groups. Our findings have implications for the careful design of assistive technologies, which should tackle shared concerns related to misrepresentation and impropriety, and also address the ethical conundrums of automatically detecting information that can further social biases.

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