# Privacy Considerations of the Visually Impaired with Camera Based Assistive Technologies: Misrepresentation, Impropriety, and Fairness

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Camera based assistive technologies such as smart glasses can provide people with visual impairments (PVIs) information about people in their vicinity. Although such 'visually available' information can enhance one's social interactions, the privacy implications for bystanders *from the perspective of PVIs* remains underexplored. Motivated by prior findings of bystanders' perspectives, we conducted two online surveys with visually impaired (N=128) and sighted (N=136) participants with two 'field-of-view' (FoV) experimental conditions related to whether information about bystanders was gathered from the front of the glasses or all directions. We found that PVIs considered it as 'fair' and equally useful to receive information from all directions. However, they reported being uncomfortable in receiving some visually apparent information (such as weight and gender) about bystanders as they felt it was 'impolite' or 'improper'. Both PVIs and bystanders shared concerns about the fallibility of AI, where bystanders can be misrepresented by the devices. Our finding suggests that beyond issues of social stigma, both PVIs and bystanders have shared concerns that need to be considered to improve the social acceptability of camera based assistive technologies.

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, bystanders, assistive technology

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## 1 INTRODUCTION

Camera-based assistive technologies are simplifying the lives of people with visual impairments by assisting them in everyday tasks such as identifying objects and colors [6], reading documents [1], and navigating through places [5, 29, 73]. With the advancement of computer vision, assistive devices are now providing more complex features to socially interact with others by recognizing faces [4, 68] and facial expressions [8], as well as providing general demographic attributes (e.g., gender, age, and height) [8] about the people in their vicinity. Wearable glasses like Orcam [4], Aira [2], and eSight [7] are gaining popularity because of their discreetness and accessibility. Recently, people with visual impairments (PVIs) have also sought help from professional agents [2] and volunteers [3] to obtain higher-quality information about their surroundings.

The increasing demand for such assistive technologies, however, raises privacy concerns for people in the vicinity (bystanders). For example, bystanders may be uncomfortable if assistive devices provide PVIs information beyond a sighted person's 'natural range' [15].[1] Bystander concerns with such technologies are not surprising; prior studies have found significant concerns raised by bystanders regarding the information captured and shared by augmented reality glasses [27, 43, 48]. Although researchers found higher social acceptability for assistive devices [33, 57, 60], there still remains stigma against the use of such glasses, and bystanders remain concerned about various uses by PVIs such as extended field or views or access to information that is not 'visually available' to sighted people [15].

In this work, we take the position that although bystanders' concerns can be stigmatizing and unwarranted, there remain some *shared* privacy concerns between PVIs and bystanders in the context of camera-based assistive technologies. As one response to bystander concerns, the use of such technologies can be argued as being 'fair' — Ahmed et al. discuss the "equity vs. equality" issue where providing more information (from an extended field of view (FoV)) may provide better 'equity' in the context of certain end goals such as equitable social interactions. At the same time, PVIs may also care about the privacy of bystanders beyond concerns about being stigmatized. Hoyle et al. report feelings of 'propriety' [63] by (sighted) camera wearers in the context of 'lifelogging' [39], and sociologists have identified the concept of 'tactful/civil inattention' [20, 34] where people deliberately ignore private information that may be available to them to provide others in their vicinity with a greater sense of privacy. Thus, we might expect PVIs to express different levels of comfort when *asking* for certain kinds of information about bystanders if they consider some types of information more 'proper' than others.

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

**R1:** (Fairness) What visually available information about bystanders do PVIs consider *useful* from a 'sighted' vs. 'extended' field of view, and why?

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

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

To answer these research questions, we conducted two online surveys with 128 visually impaired participants and 136 Amazon Mechanical 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. Participants were assigned to a between-subjects survey instrument based on the type of field of view ('sighted' vs. 'extended'). The reactions (comfort and usefulness) were studied within subjects. We conducted both quantitative and qualitative analyses to understand the information sharing and accessing preferences, as well as concerns of participants from both surveys.

Our major findings shed light on concerns about fairness, impropriety, and misrepresentation of bystanders: 1) Participants with vision impairments were much less interested in visual attributes (such as age and height) of bystanders compared to behavioral attributes (such as expression and activity). Their associated discomfort related to concerns of the *impropriety* of knowing someone's weight, for example, as well as concerns about *misrepresentation* of such information (such as gender) by algorithms. 2) Participants with visual impairments were somewhat more interested in the behaviors of people in their vicinity (e.g., whether they were smiling at them) compared to a 'normal' field of view.

[1] The natural vision range for a sighted person is a 200-degree binocular field of view [11].

In contrast, we found that bystanders were somewhat more hesitant to share this very information related to their behavioral activity compared to their visual attributes, especially in an 'extended' field of view. Our findings shed light on the views of PVIs, who consider it *fair* to receive such information in relative contrast to bystanders. 3) In general, we found that participants with vision impairments did not exhibit significant differences in their preferences based on field of view, showing that people with vision impairments don't necessarily consider an 'extended' FoV a privacy harm. On the other hand, bystanders were overall somewhat less comfortable sharing information in the 'extended' FoV. 4) Both PVI and bystander participants were concerned about bystanders being misrepresented by algorithms. They worried about the potential inaccuracy of algorithms, which could mischaracterize a bystander's attributes or actions, with social and professional repercussions. Our findings highlight the implications for designing such technologies to be sensitive to the needs of both bystanders and PVIs. Even though PVIs may have the 'right' to information through assistive devices, the quality and nature of such information is a shared concern of both PVIs as well as bystanders.

## 2 RELATED WORK

In this section, we present related work on the information requirements of PVIs 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 PVIs

People with visual impairments sometimes face difficulties to access visually available information about the people in their vicinity and about the environments they are in. The former could lead to social isolation [42, 45, 71] while the latter may cause safety and security risks, and concerns for them—Ahmed et al. reported that the number of people nearby and their identity, proximity, and activity are the most important information desired by PVIs to ensure their safety and security [13, 14, 16, 24].

Specific to information about bystanders, Zhao et al. prioritized the information needs of PVIs into: identity, relative location, physical attributes, and facial expression [75]. Krishna et al. similarly identified facial expressions, identity, and body gestures as the top categories of needed information by PVIs in their social interactions [45]. Other works also investigate the necessity of facial expression [19, 58, 62, 69], relative location [31], identity [14], gaze [13, 64], and demographics [58] of bystanders. Various camera-based assistive tools as well as smart glasses have been developed for PVIs to facilitate social interactions by recognizing faces or facial attributes of people in their vicinity [25, 41, 44, 46, 74, 75]. Some assistive applications additionally provide the approximate age, gender, and activity of a person along with face and expression recognition [4, 8]. PVIs 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 PVIs information that establishes 'equality' with sighted people in terms of what is typically observable by a sighted person.

Prior studies reported that PVIs 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) [13, 16, 36]. Therefore, more research is needed on the information needs of PVIs beyond a sighted person's field of view. One of our goals is to understand the perspective and comfort levels of PVIs 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 PVIs consider fair and appropriate in seeking.

### 2.2 Social acceptability of assistive devices

As PVIs 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 PVIs and bystanders as a way to improve the social acceptance of wearable cameras [47]. Prior works have investigated social acceptability and privacy issues for assistive technologies from the perspective of their users [32, 48, 49, 52, 72]. Garg et al. found that the adoption of assistive technologies by older adults depends on the perceived usefulness of the system [32]. Shinohara and Wobbrock observed how participants avoided using assistive technologies because of the associated social stigma [66]. However, beyond the concerns of being stigmatized, PVIs 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 [20, 34]. Hoyle et al. reported that lifeloggers with wearable cameras show *'propriety'* [63] behaviors by not sharing certain photos of other people or turning off their lifelogging cameras [39]. Akter et al. observed that PVIs are more concerned about the privacy of bystanders than their own while using image-based, human-assisted question answering services [18].

To understand the perspective of bystanders, Denning et al. studied people's reactions to the presence of augmented reality wearable devices [27]. They found that various factors can influence a bystander's perspective toward 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 [67]. 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 that 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 [43]. Nguyen et al. reported concerns relating to information privacy when people are video recorded including notification or consent, improper access, and unauthorized secondary use [56]. Hoyle et al. reported extreme cases when bystanders avoided interactions with the device wearer [39].

In the context of assistive devices, researchers reported that bystanders are more positive about sharing information with people with disabilities as compared to people without disabilities [15, 60]. Ahmed et al. found that bystanders expressed hesitance to share information with PVIs through interactions that were not 'natural' from a sighted person's perspective [15]. In this study, in addition to studying the perspective of both PVIs and bystanders, we investigate the impact of sharing information on social acceptance based on two fields of view (sighted and extended).

### 2.3 Fairness in information access

Assistive technologies for PVIs 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, 8], gaze [61, 62], and activity [2, 8]. 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 [30, 54]. 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 [15]. 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 [15]. 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 where we focused on the needs and concerns of PVIs when receiving information about bystanders from augmented reality devices (such as Google Glass or Microsoft Hololens) and concerns of bystanders about sharing such information.

### 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) a sighted person's normal field of view, i.e., in front of the glasses (*FoV sighted*), or b) all directions, including from behind the wearer of the glasses (*Fov extended*).

### 3.2 Visually available information

Each survey sought to measure the privacy concerns of PVIs when receiving 11 'visually available' types of 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 [15, 45, 75]. Ahmed et. al considered six types of visually available information in the context of a bystander's willingness to share their information: demographics (age, gender, race), height or weight, gaze, activity, appearance, and emotion (happy, sad, stressed) [15]. 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 [45]. Along with this information, Zhao et al. found that information about whether someone is available for conversation is also important in social activities [75]. Inspired by prior studies, we asked the participants about their comfort levels with receiving 11 visually available types of 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.

### 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 each visually available information, as well as their 'usefulness,' each using a 5-point Likert scale.

The wording of the description and questions varied slightly based on the two FoV conditions. – 'sighted' and 'extended.' When describing the glasses, we mentioned only forward-facing cameras for sighted view, whereas for the extended 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 sighted view condition, whereas for the extended view condition they were asked to consider that the bystander is 'behind them.'

Specifically, we asked these two questions to PVIs with a Likert item for each of the 11 types of visually available information:

***Q1.*** *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).

***Q2.*** *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).

For the bystander survey, we asked the following two questions to investigate the comfort level of bystanders. To avoid social acceptability bias, we added the following clarification: 'Although some people are comfortable sharing such information, some may not feel comfortable. We are interested to know how you feel along this spectrum'.[2] We considered the same 5-point Likert scale used in the PVIs survey.

***Q1.*** *How comfortable would you feel about a PVI getting various information about you through assistive glasses when they are [facing/facing away from] you?*

***Q2.*** *How reasonable it would be for a PVI [facing/facing away from] you to get information about you through the assistive glasses?*

### 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 for PVIs to receive 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) [10] and the American Council of the Blind (ACB) [9]. 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.

[2]We pilot tested three different phrasings (without the clarification, with the clarification, and clarification with examples) but did not see any significant differences in the responses.

Respondents for the bystander survey were recruited from Amazon Mechanical Turk for a '15-min survey on information sharing preference with PVIs'. Respondents were required to be 1) residents of the United States for at least five years to control cultural variations [40]; 2) 18 years or older; 3) 'workers' of MTurk with an approval rating of at least 98% on at least 1,000 completed HITs to ensure a higher quality of responses [53]. To ensure high-quality data, we added a captcha at the beginning of the survey, and one of the attention check questions was added as image. 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 incorrect attention check, we were left with 136 participants (out of 156 participants).

### 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 is likely to stimulate voluntary participation and high-quality responses [23]. At the same time, 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. After collecting 136 responses, we performed the random drawing, selected 14 (approximately 10%) participants, and paid each of them with $20 Amazon e-gift certificates. We emailed them the link of the e-gift certificates within three 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 used 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).

### 3.8 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 a 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 ('sighted' and 'extended'). 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. Finally, we present a comparison of comfort levels between PVIs and bystanders.

### 4.1 Demographics

A total of 136 people with visual impairments participated in our first 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. For the bystander-focused survey, after validation, the sample comprised 136 responses (out of 156 responses). Of these, 64 PVIs and 68 bystanders received the 'sighted' FoV condition, and 64 PVIs and 68 bystanders received the 'extended' FoV condition. Participant demographics for the two surveys are listed in Table 1. Among the visually impaired participants, 84 (65.6%) were totally blind, and 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).

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%).

| | PVIs | Bystanders |
|---|---|---|
| **Gender** | | |
| Female | 88 (68.8%) | 59 (43.4%) |
| Male | 40 (31.2%) | 77 (56.6 %) |
| **Age** | | |
| 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%) |
| **Education** | | |
| 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) |

Table 1. Demographic information of participants.

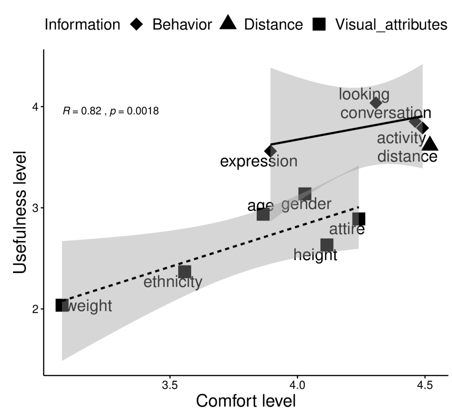
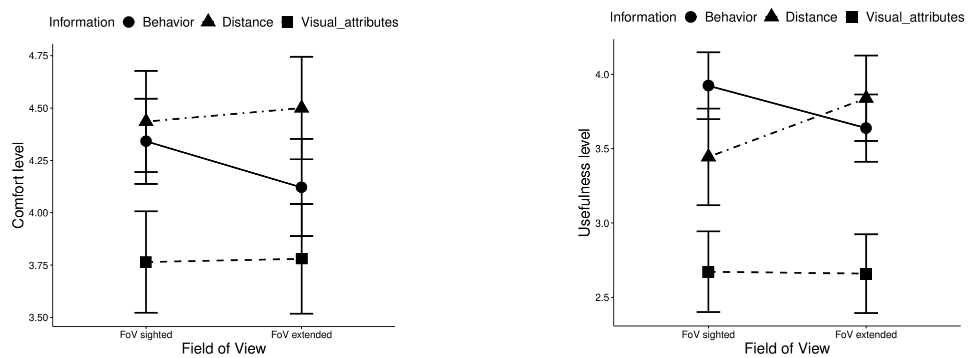



Fig. 1. Correlation between usefulness and comfort level of receiving information with regression lines and their confidence intervals (PVIs).

### 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 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.




(a) Comfort level

(b) Usefulness level

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% 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% CI $[3.6, 3.9]$) ($p = 2e^{-16}$) as well as (Cohen's $d$: 0.7) distance ($\mu = 3.64, \sigma = 1.22,$ 95% 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 types of 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 sighted FoV condition ($\mu = 3.92, \sigma = 0.89,$ 95% CI $[3.7, 4.1]$) as compared to the extended FoV ($\mu = 3.63, \sigma = 0.89,$ 95% CI $[3.4, 3.9]$).

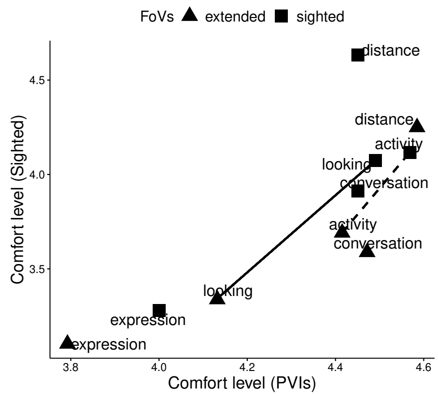



Fig. 3. Relation between comfort level of bystanders and PVIs

Overall, we find that behavioral information is more useful to PVIs in the sighted FoV compared to the extended FoV (e.g., typically behavior cues are more important in face-to-face conversations 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 extended fields of view; as we discuss in our qualitative findings, PVI participants mentioned it as 'fair' to receive information from an extended 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 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 we 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% CI $[3.5, 3.9]$) compared to the comfort level of PVIs for receiving that information ($\mu = 4.3, \sigma = 1.05$, 95% 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% CI $[3.7, 4.1]$) compared to the comfort level of PVIs ($\mu = 4.42, \sigma = 0.96$, 95% CI $[4.2, 4.6]$) ($p = 2.7e^{-05}$).

Additionally, we 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 that 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% CI $[3.5, 3.8]$) as compared to information about their visual attributes ($\mu = 3.85, \sigma = 1.03,$ 95% CI $[3.7, 4.0]$) ($p = 0.0012$) and much more in the case of distance ($\mu = 4.44, \sigma = 0.98,$ 95% CI $[4.3, 4.6]$ ($p = 4.5e^{-14}$) (Cohen's $d$: 0.64). Bystanders also reported a higher comfort (Cohen's $d$: 0.5) level for distance as opposed to visual attributes ($p = 4.4e^{-11}$).

*Field of view preferences.* Figure 3, however, also illustrates consistent bystander discomfort about sharing information in the extended FoV compared to the sighted FoV. We conducted Wilcoxon rank-sum tests to observe the interaction between different FoVs and comfort levels of PVIs and bystanders for different information (behavioral and distance). We observed significant differences across the two FoV conditions for both bystanders and PVIs for the information whether the bystander is 'looking' at PVIs ($\chi^2 = 10434, p = 0.0002$) (solid line). For the 'activity' of the bystanders, the comfort level of bystanders were marginally significant ($p = 0.055$) (dashed line). In general, our bystander participants were somewhat less comfortable (Cohen's $d$: 0.3) in the extended view condition relative to the sighted view when sharing 'looking' and 'activity' information.

Overall, we see that bystanders were comfortable with sharing their distance information. However, although behavioral information is most useful to PVIs – and they feel comfortable seeking it – bystanders are relatively uncomfortable sharing information about their behaviors. There is also a small overall effect of bystanders being less comfortable sharing their information in the extended FoV. However, we observed a larger effect related to 'looking' and 'activity' in an extended 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% CI $[3.4, 3.9]$) with PVIs than male participants ($\mu = 4.0, \sigma = 1.0,$ 95% CI $[3.8, 4.3]$). However, as we observed earlier, visual attributes were deemed less useful by PVIs 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 PVIs 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% CI $[3.8, 4.0]$) than the totally blind participants ($\mu = 4.1, \sigma = 1.21,$ 95% CI $[4.0, 4.2]$) about receiving information about bystanders.

We conducted an overall Wilcoxon rank sum test to explore the effect of the 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 PVIs in receiving information of bystanders. Our findings indicate that people with visual impairments find it less necessary 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 an extended 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 sighted FoV as compared to the extended FoV. 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.

### 5.1 Misrepresentation of information

Representation of self [34] 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 experiences when assistive devices failed to provide accurate information, making 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 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 also 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 toward 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 [66]. 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 extended FoV as sighted people can not see behind them. One participant compared receiving information from extended 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 PVIs 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. PVIs 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 [63].

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 toward 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 we find agreement on certain attributes being 'improper' beyond issues of stigma imposed by bystanders.

### 5.3 Toward achieving fairness

Although previous work indicated that bystanders were uncomfortable with PVIs receiving information from an extended FoV [15], recall that we found the PVIs do *not* consider this to be 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 an 'extended' FoV along with the 'sighted' 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 sighted 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 an extended 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 an extended 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 toward sharing visually available information with PVIs. Although several bystander participants expressed discomfort with an extended FoV (we omit these quotes since they are in line with previous findings [15]), 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 an extended 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]

However, we found that bystander participants were more hesitant to share 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 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.

## 6 IMPLICATIONS

Although assistive technologies can be helpful to PVIs when engaging in social interactions, our participants reported several *shared concerns* related to the fallibility and invasiveness of such devices, and disagreed on some issues of fairness. Here, we identify implications for design based on our findings that could increase the acceptability and utility of camera-based assistive technologies to both PVIs and bystanders.

### 6.1 Fairness and equity

PVIs are equally comfortable in receiving information from both sighted and extended FoVs. PVIs considered it 'fair' to receive information from the extended FoV 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 PVIs in receiving information from an extended 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 PVIs when they are not directly facing the person.

In the context of information needs, PVIs consider behavioral attributes (e.g., gaze, expressions, activity) as most useful for social interaction. Although such preferences have also been identified in previous work [13, 45, 47], 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). Bystanders raised concerns about giving precise or specific numbers (such as one's weight) that sighted people cannot perceive easily and described it as 'mortifying.'

Similar to our findings, Lee et al. also experienced hesitance from bystander participants in sharing facial expressions and head pose [47]. 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 PVIs and bystanders when information is provided from an extended field of view and how to appropriately convey behavioral information about people without mischaracterizing their intentions.* Prior work has found that people's perceptions change toward a technology with repeated exposure [27]. Profita et al. reported that wearable devices have more social acceptability if it visually indicates that the device is being used for assistive purposes [60]. Grayson et al. suggested using different light indicators to alert bystanders of the type of information the system is recording [35]. We also observed similar ideas from our visually impaired participants, who felt more comfortable receiving information if the cameras were visible to the sighted people, 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 PVIs and improve their willingness to provide information from an extended 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, behavioral), where the information is being analyzed (e.g., locally or in the cloud), and the purpose for such collection [60].

### 6.2 Propriety concerns

PVIs shared 'propriety' concerns about accessing information about bystanders and described it as a violation of bystanders' privacy when receiving information about 'personal' 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 [20, 34, 37]. 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 shared concerns about PVIs being judgmental by receiving information about them before knowing them in person. They were concerned about being judged by their appearance upon receiving such information by PVIs. Some considered it as the invasion of their privacy when it comes to sharing their behavioral and sensitive information (e.g., emotion or age). *Our findings suggest that future assistive devices should also focus on the 'propriety' concerns of PVIs.* Although receiving some information may be stigmatized by bystanders, PVIs 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.) [63]. Assistive technologies could allow PVIs 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 PVIs feel like privacy violators from their own perspective.*

### 6.3 Fallibility of AI: Misrepresentation and accuracy

Participants from both surveys were concerned about the accuracy of the assistive devices and misrepresenting information about bystanders to PVIs. Both parties were concerned about embarrassing situations that might be caused by having inaccurate information and acting upon those in social interactions. Regarding accuracy, participants were most concerned about inferring subjective information such as emotion, gender, and ethnicity. Such concerns about the accuracy of AI is also discussed in prior work [17], which observed that PVIs often prefer professional agents or volunteer-based technologies for obtaining answers of higher quality. *It is thus imperative that designs of such devices – if they are to rely on automated inferences – convey accuracy or confidence information to PVIs.* Macleod et al. found that the trust of PVIs on automatically generated captions is highly correlated with the confidence reported by the algorithm [50]. 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 audio/visual prosodic cues (such as intonation and fillers) contribute to the perception of confidence in the answers given by people [28]. Assistive technologies should incorporate such cues to convey confidence to PVIs, 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 [55]. Multiple captions can also help PVIs to have a better understanding or improved judgment about the situation [55]. Recent work has focused on the bias and fairness issues of AI and their effect on people with disabilities [30, 54, 70]. They advocate to include people with disabilities in application design and development, and to 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

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. Our participants were limited to one geographic area (the United States), and so our findings may not generalize to other regions. Our samples for the two surveys are gender imbalanced, and it is well-known that privacy concerns can differ with gender [18, 38, 65]. We found little or no significant gender differences in our quantitative analysis, however.

One concern could be the use of an online survey, which gives a verbal description of a more abstract technology rather than a paratyping [15] or a prototype-based [12, 47] 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 [22, 26, 51] and are often encouraged, e.g., to avoid the difficulties people with disabilities may face traveling to the facility [59], and are more suitable as participants use their preferred screen readers in their own settings [21]. One concern is that bystanders, too, may not grasp the subtleties of how PVIs make use of information from such devices in a survey based study. Again, we wanted to capture general perceptions not tied to a particular prototype and based on their general perceptions of PVIs.

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

We conducted two online surveys to understand the information needs and the shared concerns of people with visual impairments and bystanders in the context of camera-based assistive devices. In terms of 'fairness,' we found that people with visual impairments desire information about people from both a sighted person's field of view as well as an extended field of view (e.g., from behind them), and are comfortable doing so in both scenarios. At the same time, bystanders are less comfortable sharing information from an extended field of view, which they consider to be 'unnatural.' In the context of 'impropriety,' we found PVIs 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 PVIs and bystanders about how much information is 'too much information.' Finally, we found concerns about 'misrpresentation' through fallible artificial intelligence (AI). We found that both sets of participants had significant concerns about the accuracy of information from AI-based assistive solutions as they could lead to misunderstandings and the misrepresentation of bystanders. Our findings have implications for the careful design of such technologies, which should tackle shared concerns related to misrepresentation and propriety, and also address the mismatch in perceptions of fairness between bystanders and people with visual impairments when obtaining behavioral information beyond a 'natural' field of view.

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