Up to a Limit? Privacy Concerns of Bystanders and Their Willingness to Share Additional Information with Visually Impaired Users of Assistive Technologies

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The emergence of augmented reality and computer vision based tools offer new opportunities to visually impaired persons (VIPs). Solutions that help VIPs in social interactions by providing information (age, gender, attire, expressions etc.) about people in the vicinity are becoming available. Although such assistive technologies are already collecting and sharing such information with VIPs, the views, perceptions, and preferences of sighted bystanders about such information sharing remain unexplored. Although bystanders may be willing to share *more* information for assistive uses it remains to be explored to what degree bystanders are willing to share various kinds of information and what might encourage additional sharing of information based on the contextual needs of VIPs. In this paper we describe the first empirical study of information sharing preferences of sighted bystanders of assistive devices. We conducted a survey based study using a contextual method of inquiry with 62 participants followed by nine semi-structured interviews to shed more insight on our key quantitative findings. We find that bystanders are more willing to share some kinds of personal information with VIPs and are willing to share additional information if higher security assurances can be made by improving their control over how their information is shared.

CCS Concepts: • **Human-centered computing** → **Ubiquitous and mobile computing theory, concepts and paradigms**; • **Human-centered computing** → *Empirical studies in collaborative and social computing*; Accessibility technologies; • **Security and privacy** → Usability in security and privacy;

Additional Key Words and Phrases: Assistive Technologies, Paratyping, Information Sharing

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1 INTRODUCTION

One of the goals of researchers of assistive technologies for visually impaired persons (VIPs) is to bridge the information gap caused by the loss of vision. Hence the designers of such technologies are constantly striving

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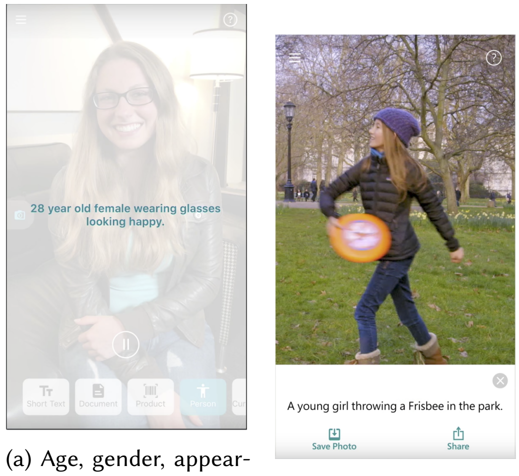


(a) Age, gender, appearance, and facial expression

(b) Age, gender, and activity of a nearby person

Fig. 1. Seeing AI providing various information about people nearby [54].

to push the boundaries by extracting and sharing with the VIPs as much information about the environment as possible and as needed by the VIPs. Building on recent advances in computer vision, various camera based assistive applications like Seeing AI [54], BeMyEyes [25] and AiPoly [7] have gained traction, and wearable glasses like OrCam [58], Aira [9], eSight [23] are coming to the market. Using data from camera feeds, these solutions help VIPs in performing various basic tasks such as recognizing objects and reading texts in near-real time [9, 14, 23, 25, 54, 58]. With the improvement of computer-vision based techniques and machine learning, devices have started to incorporate more complex features such as recognizing people nearby and interpreting the environment through 'scene understanding' [7, 9, 23, 54]. Figure 1 depicts two examples of Seeing AI where the app describes the people nearby and their activity.

The rise of such applications raises the question *to what degree it is appropriate to provide information about the environment for assistive purposes*. People in the vicinity of augmented reality (AR) devices — the 'bystanders' — may have significant privacy concerns as was documented by Denning et al. in the context of sighted wearers of AR glasses [22]. Indeed it is believed that one of the main reasons that Google Glass failed was that it made bystanders uncomfortable about their privacy.[1] Researchers have found, however, that bystanders are generally more accepting towards assistive devices [29, 56, 61]. A better understanding of how bystanders might be willing to share information with VIPs, even if they may feel generally uncomfortable with AR, may allow greater acceptance of such technology. In fact, bystanders may be *more* willing to share personal information with VIPs in the context of specific assistive uses than with sighted device wearers (and indeed, we find it to be the case in this work).

The specific information sharing preferences of bystanders for assistive purposes, however, is not adequately understood; even though bystanders may be willing to share more information with VIPs, we do not expect bystanders to be 'infinitely' willing. We ask, *where do people draw the line for sharing additional information with VIPs?* Do people think VIPs should be given access to the 'same' information visually available to a sighted person ('equality'), or instead provided with additional information to help them overcome existing barriers ('equity')

[1]https://www.theguardian.com/commentisfree/2017/jul/23/the-return-of-google-glass-surprising-merit-in-failure-enterprise-edition

to achieve various goals? In general, a balance will exist between where bystanders feel that the additional information is justified in various contexts despite their privacy concerns if the information is used for assistive purposes.

Although one may posit that VIPs should attain equity for their specific goals, and may be 'deserving' of the necessary information, in reality the wearer of such devices will need to account for the privacy concerns of bystanders if such devices are to become commonplace and accepted. Our longer term research goal is to characterize and influence the relationship between what VIPs require to attain equity and the willingness of bystanders to provide such information. Although future work will need to address how to bridge any gaps and influence attitudes (e.g., in the extreme, of 'ableist' bystanders who may be prejudiced against such sharing), in this paper we take a first step to understand how bystanders are willing to share differing amounts of information based on whether the wearer of the AR device is sighted or a VIP. The benefits of such a study are that at a minimum, it can bring out issues that need to be considered before such technologies become widely used. In addition, it may guide the technology development as well as its deployment and use with necessary safeguards to address such privacy concerns.

Finally, such wearable camera based technologies are not limited to people with visual impairments. Indeed, makers of AR technologies have targeted a broad population with myriad applications that analyze and enhance one's interaction with the environment. For example, besides Google Glass, Microsoft's HoloLens[2] enables its users to generate and manipulate multi-dimensional full color holographic objects by using the user's gesture, gaze, and voice. Other applications such as the HoloLens Remote Assist app[3] allow experts to provide remote assistance to workers. In general, we expect in the near future people with a wide range of abilities — with or without visual impairments — will make use of wearable cameras and assistive AR solutions. In a mixed environment with such devices also serving the assistive needs of users it is imperative to understand how and when to provide information about the environment to users of such devices based on their relative information needs and the concerns and attitudes of the bystanders.

Our study. To understand the information sharing preferences of bystanders with VIPs as compared with sighted users of AR, we conducted an event-contingent contextual method of inquiry called 'paratyping' [38, 56] with 62 participants in three different workplace contexts. Although such assistive devices will eventually be used in various social contexts, because of the recent negative reception of devices such as Google Glass stemming from privacy concerns, in the nearer term these devices show the greatest promise for use in controlled environments such as the workplace [19, 30]. Google Glass, for example, has numerous "Glass Partners"[4] focused on enterprise applications. Thus as a first step we start by studying information sharing preferences in the workplace context. More generally, information sharing practices will be context dependent and depend on the social relationships between the bystander and the device wearer, and future work should further study the use of assistive devices in public contexts.

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

RQ: *What personal information, and to what degree, are bystanders willing to share with vision impaired co-workers compared with sighted co-workers in the context of camera-based (assistive) technologies?* Our study sheds light on the factors of information sharing preferences with visually impaired co-workers and provides further insight into how much more willing people are to share certain kinds of information with people with visual impairments.

[2]Microsoft HoloLens: https://www.microsoft.com/en-us/hololens
[3]https://mashable.com/2018/05/07/microsoft-remote-assist-layouts-mixed-reality-collaboration/
[4]Glass Partners: https://x.company/glass/partners/

Two researchers (one visually impaired and one sighted) wore a Microsoft HoloLens[5] device in a cafeteria, two meeting rooms, and in the work areas in two different workplaces. Another researcher handed out our survey instrument to those participants who noticed the device and exhibited curiosity. To gain deeper insights into our quantitative findings we followed up with 9 participants and interviewed them on their information sharing preferences. We also note that although VIPs *as bystanders* will also have privacy concerns, we assume that VIPs will be more willing to help other VIPs, and therefore we do not study the attitudes of *VIP bystanders* in this work. Instead we study only the attitudes of sighted bystanders.

2 RELATED WORK

We present related work on camera-based assistive solutions and privacy and ethical concerns relating to the use of camera and computer vision technologies both by sighted persons and by VIPs.

2.1 Cameras for Better Accessibility

With the decreasing costs and increasing capabilities of cameras and their obvious implications in the context of assisting VIPs, there has been considerable research on assistive technologies for VIPs using cameras. Researchers have explored various camera based solutions for helping VIPs in wayfinding [20], navigation [27], reading from appliances [32], and recognizing objects [14, 35]. Since composing photos is particularly challenging for people with visual impairments [3, 40], several camera based applications to aid VIPs in taking photos have been developed [2, 3, 13, 40, 71]. The propensity of research towards camera based assistive solutions [4–6, 44, 60] and the recent advancement in computer-vision based algorithms [34, 46] indicate the dominant role of cameras in assistive solutions with various products being proposed [9, 55, 58].

2.2 Information Needs of VIPs about People in the Vicinity

Almost all new assistive wearable and mobile camera based devices support face recognition and can collect various facial features and provide that to VIPs for enhanced social interaction. Recognizing people and information about familiar faces nearby is important for people with visual impairments [74], as otherwise it limits their social interaction [18, 44, 65] and raises security and safety risks [4, 6, 15, 39]. For that reason, the need for information about people in the vicinity has been reported by multiple previous researchers. Ahmed *et al.* [6] conducted a study with 19 visually impaired people and reported that the number of people nearby and their identity, proximity, and activity are the most important pieces of information to maintain their safety, security, and privacy. Zhao *et al.* [74] reported the importance of recognizing people for social interaction and identified that the identity, relative location, physical attributes, and facial expressions are most preferred by the VIPs. Krishna *et al.* [44] reported that facial expressions, identity, and body gestures are three important pieces of information that VIPs need during social interaction. Similarly, various other works have reported the necessity of identity [4, 51, 60, 66], relative location [28, 66], facial expressions [10, 59, 62, 68], gender [59], and gaze [4] of people nearby.

In light of the above, researchers have proposed various systems which can provide such details of nearby people to VIPs. There are multiple applications and prototypes available for the blind which can effectively recognize familiar faces [16, 42, 44, 45, 73, 74], facial expressions [10, 43], and find the relative location [63, 66] of nearby people. Applications like Seeing AI [54] can provide several types of visual information about nearby people including different facial characteristics, emotion, approximate age, and their activity (Figure 1). Already various applications are collecting and sharing detailed information about people nearby to people with visual impairments. All of the above research has focused on the needs of receivers (the VIPs), whereas we focus on the perspective of bystanders and their comfort levels with sharing various types of information.

[5]Microsoft HoloLens: https://www.microsoft.com/en-us/hololens

2.3 Bystanders' Privacy Issues

Since the introduction of Google Glass, the negative reactions of bystanders and their attitudes towards wearable cameras have been considered as the major barriers to acceptance and deployment [52]. Denning *et al.* explored bystanders' reactions towards augmented reality devices and reported various factors such as camera subtlety, place, purpose, and method of recording can affect people's feelings towards new ubiquitous devices. Hoyle *et al.* reported bystanders' reactions towards wearable lifelogging cameras and reported that bystanders are mostly accepting of such devices though they also reported some extreme cases where people avoided interaction with the device wearer [37]. Koelle *et al.* studied social acceptability of data glasses in various hypothetical scenarios and reported how factors such as gender, type of device (e.g., smartphone or data glasses), and information of data collection can be associated with the attitudes of people [41]. Lee *et al.* studied information disclosure concerns on wearable devices via exploring various data exposure scenarios [48]. Although these studies did not study assistive devices in particular, there has been some research in the assistive technology domain on bystanders' reactions towards the use of assistive devices. Most of these studies [29, 53, 56, 61] reported that wearable devices are more socially acceptable if the devices are being used for assistive purposes. None of the studies, however, have considered the specific information sharing preferences and concerns of bystanders in the context of assistive devices. Although people may have reservations when such information is available to *sighted* bystanders, it may be the case that they are much more willing to share particular types of information with VIPs. In our work, for example, we focus on such information sharing preferences across three specific categories of information: publicly available information, visual information, and information about one's physical presence.

2.4 Ethical Issues of Camera Assisted Technology

Camera based devices can collect rich visual information and create additional privacy risks for both the camera user/wearer and bystanders. For example, Templeman et al. demonstrated how malware can map a camera owner's environment without their knowledge [70] and intrude upon their physical space. Such threats can potentially have a much higher impact on the visually impaired because they cannot review the content of photos or be less aware of when such attacks are being carried out [6]. Malicious parties can use such malware to record photos or video of private moments and blackmail the camera owner.

In the context of computer vision, Acquisti et al. discuss the privacy implications of face recognition in the context of AR technology [1]. Face recognition is linked with identity theft [1], and issues of bias related to race [17] and age [11]. In the wrong hands, or simply based on the accuracy of information provided to users, cameras and computer vision based technologies for assistive purposes raise ethical concerns related to misrepresentation of bystanders as well as (implicit) bias by the camera wearer based on such information. Face recognition, however, can provide great benefits to people with visual impairments and therefore it is essential to study the balance between the needs of VIPs and the comfort levels of bystanders in the context of AR applications. We further discuss the challenges stemming from these ethical concerns in Section 6.7.

In the context of providing advice to policymakers, Roesner *et al.* [64] discussed legal questions raised by the use of augmented reality devices. They discuss issues pertaining to input (e.g. constant recording), data collection and storage (e.g., how the data will stored and analyzed), and output (e.g., providing incorrect information).

3 STUDY DESIGN

There are several factors and rationale related to our methodology, which we discuss next.

3.1 Paratyping

In this study, our goal is to understand the information sharing preferences of the bystanders of assistive devices. We face two challenges in acquiring this information: First, most sighted people have very little experience interacting with VIPs and hence may not appreciate the nature and importance of everyday information and their implications for VIPs. Second, since assistive technologies are not yet widely used, their capabilities and limitations are not well known. This may lead to one of two extreme perceptions and color the responses of the average sighted individual to a standard survey questionnaire. At one end, they may assume that technology is so powerful that if they consent to a bit of sharing, somehow their privacy may be compromised and hence respond very conservatively to sharing. At the other extreme, one may not be aware of the immense progress in recent times on such technology and assume that very little information may possibly be extracted by technology and hence respond very liberally to information sharing questions.

To overcome these challenges, we conducted a combination of 'paratyping' and in-depth interviews [33, 38]. Paratyping is an event-contingent, contextual method of inquiry and helps to evaluate ubiquitous technologies in a real-world context [38, 56]; a paratype is "a simulation of interaction with a technology, which is evaluated alongside real-world experience" [38, 56]. This method was previously used to evaluate the privacy concerns of augmented-reality devices [22], portable memory-aid devices [38], and lifelogging devices [56]. Since subjects do not have any experience with new ubiquitous assistive devices, we used paratyping to simulate the future experience. The paratyping study was followed by in-person semi-structured interviews. We recorded participants' responses about sharing in three categories of information. These categories were selected based on multiple brainstorming sessions between the authors, one of whom is visually impaired.

3.2 Identifying Information to Share

In the context of information about people, we want to provide VIPs with a set of information that will maximize their comfort in interactions with other people. As mentioned earlier we focus on workplace environments where such devices are being deployed first, and focus on such environments where both sighted people and VIPs work. In particular, we chose a technology/research workplace (the authors' workplace at the time of this research) as the setting for the study. In such an environment one can assume that all the persons present are either employees or validated visitors with no unknown persons being around.

Given the choice of workplace context, the assistive technologies for VIPs should provide information that will aid them in enhanced interactions with their coworkers in the workplace. We select the categories of information to be studied based on this constrained environment. For the current study, we identified three categories of information: publicly available information, visually available information, and physical presence information, each of which is explained below. Since physical presence information is somewhat visual information, we present only two categories to our participants in the paratyping study. In the interview study, we explored all information categories in depth. We discuss the rationale for selecting these three categories of information next:

3.2.1 Publicly Available Information. In the context of the work environment of this study, publicly available information refers to details of a person including the name, designation, which group the person belongs to, academic qualification, college attended, and so on. Some of these may be available more readily than others: for example, the ID cards mandated by most workplaces, have the name and some color code to signify the work group. A notice board may have pictures and names. The internal website will have more details. Knowing a person's full name one can search social media sites to find even more information. For a sighted person, the ability to see a face and to either recognize it or remember it is adequate to find all of the above information with one or more further steps. For instance, one of the co-authors of this paper frequently needs to refer to the photo wall in the office to recall a colleague's name. Such an option is unavailable to a VIP and hence the need to directly present a range of such publicly available information to the VIP based on face recognition technologies. Face recognition technology actually allows us to do that: given a photo we can search for it in different databases to then infer the name of the person [72]. It has been shown that simple face recognition can even retrieve various kinds of sensitive information such as US social security numbers [1].

We considered five categories of information: demographic information, contact information, work related information, educational background information, and information from social media. In each category, we have a list of subcategories with mostly public information. In each category, we included at least one kind of quasi-identifiable information that might be considered private such as age, grades, and relationship status. We have the following subcategories:

- Demographic Information: Name, age, birthday, exact height and weight, picture.
- Contact Information: Name, address, email, phone number, instant messenger ID.
- Work Information: Name, basic work information (e.g., desk number, mentor, designation), work email, project, past work history.
- Education Information: Degree title, educational institute, graduation year, courses taken, extra-curricular activities.
- Social Media Information: Name and ID, number of friends or followers, number or name of mutual friends, relationship status, political or religious views, recent status/post/tweets, hometown.

To reduce fatigue, we did not include more than seven information types in each category of information. We constructed this list by exploring multiple colleagues names across various platforms (e.g., Facebook, LinkedIn, employee profile, personal website) to understand the types of information commonly available.

3.2.2 Visually Available Information. By visually available information, we refer to information that can be inferred by a sighted person looking at other people, such as their approximate age, approximate height/weight, their appearance, and their current activity (eating, talking, reading, etc.). Knowing a person's activity, for example, can help in observing whether a colleague is busy and if they should be approached later. We again constructed a list of six items: demographic information (age, gender, race), approximate height or weight, gaze, activity, appearance, and emotion (sad, happy, tired, stressed). For the meeting room scenario, discussed later, we added the person's relative location (where they are seated). We constructed this question based on the findings of Ahmed *et al.* [6] and our past experiences with VIPs.

3.2.3 Physical Presence Information. VIPs are sometimes unaware of the presence of a co-worker and this sometimes leads to embarrassing situations [4]. In our study, we wanted to explore whether sighted people feel comfortable sharing their presence information with VIPs. In the paratyping study we asked participants preference on sharing their physical presence information when they are nearby and when they are not nearby the VIP. However, there are many subtleties involved with physical presence information: A person sitting behind another person is not directly visible, or when a person chooses a seat away from another person so as to be not easily spotted. In both cases, the person is 'nearby' but not directly visible. Hence we divide physical presence information into two categories: 'present nearby and visible' (i.e., directly visible) and 'present nearby but not visible' (e.g., the person is hidden from direct view such as behind a wall or in the next room). Since, this distinction is very complex and difficult to understand, we did not explain or describe this distinction in the paratyping study. By presenting some hypothetical scenarios, we explored this information in depth in our interview study.

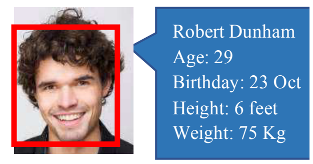
3.3 Rationale for Using HoloLens

We considered three possible devices for our study: the HoloLens, which is a head-mounted mixed (augmented and virtual) reality device, a clip-on attachment to a spectacle, and a smartphone along with a headphone that is held up in front of a person to capture information. We chose the HoloLens since we wanted a visible, obviously high-tech device that could plausibly extract the information that we claimed to be extracting. The use of the subtle device was avoided since the negative publicity to such wearable devices created by the introduction of the Google Glass without such privacy considerations is still fresh in people's minds. Holding/waving of a

HoloLens is a wearable mixed reality device. The device is a small personal computer with lots of advanced features and connected to the internet. It has the power to compute and process visual information in nearly run time. HoloLens has a speaker that can continuously provide information to the user.

Researchers are exploring various ways to help people **have a better social interaction** by using HoloLens. Consider that, HoloLens can **collect your photo** and try to find some **information** about you **by searching different platforms** (e.g., employee database, your Facebook/LinkedIn/Twitter account, your personal website, and others). The device will analyze the captured photo and find some information available online (e.g., your age, your background history). The device can also analyze some facial feature and get some visual information about you (e.g., your stress level). Our team wants to know about **your feelings** about the information being collected by HoloLens.

If you saw someone wearing this device in the cafeteria, then the person probably has seen an image like this in the device. Therefore, the person probably knows **your name, your exact age/height/weight and birthday**. We want to know your feelings about the provided information.



Our research team will keep your answers anonymous and confidential. If you are willing to join this research, then please complete the following survey as soon as possible. The survey should only take you a few minutes to complete. If you don't want to participate then you do not need to return this survey. You can either return it now, or you can return it later to **Mr. X** at desk no: 0000. By returning your completed survey, you are agreeing to join this research. **Thank You**.

Fig. 2. Study Card Description

smartphone may be considered impolite in office spaces and more intrusive than a headset based solution. The HoloLens in practice achieved our objective: people were polite and did not stare at the device, but it was still noticeable and they would steal quick glances at it and it is those people that we reached out to take our survey.

4 METHOD

In this section, we discuss our study methods and procedures:

4.1 Paratyping Study

In the paratyping study, two researchers (one visually impaired and one sighted) wore a Microsoft HoloLens device, and roamed around in different office contexts. We conducted the study in two workplaces, one in the researcher's workplace and another in a different research organization. Both of the workplaces are technology-oriented work organizations where the employees were predisposed to admit the plausibility of such assistive technologies with capabilities of extracting the range of information discussed in the study, which allowed us to elicit their informed responses.

Across five sessions, the researchers wore the HoloLens in three office contexts. In each session, the device wearer wore the HoloLens and performed their natural activity for the particular context. In the cafeteria, ate their lunch or evening snacks; in the meeting room attended a meeting; and in the office place, roamed around the workplace. In each session, another researcher noticed the bystanders' reactions and handed out a paper survey to those participants who noticed the device. The survey was completed immediately by some and others completed it and returned later to the researcher.

4.1.1 Structure of the Survey. In the survey, we handed out a study card to participants that introduced the HoloLens, its potential use to acquire information, and described the objective of the study and the nature of their participation. Figure 2 shows the description section of our survey. We also provided our contact information for returning the survey to us later.

After the above description, the participants were asked a set of questions. The first question was about their information sharing preferences with the device wearer, who was sighted. Following that, we asked their information sharing preferences if the device wearer was visually impaired. We specifically asked the following question to the participants:

> *How would you feel if the following information about you is shared with the person wearing HoloLens?*

We adopted this question from Lee *et al.* 's study on information disclosure concerns in the context of wearable devices [48]. We used a similar 5-point Likert scale ranging from "indifferent" to "very upset" for the response [26, 48]. Like them, we assumed that people are likely to be upset, at least a little because we are disclosing information without their permission.

For the sessions with the visually impaired wearing the device, we switched the order of the questions. Therefore, the first question asked about their information sharing preferences with the device wearer who was visually impaired. The second question asked about a sighted device wearer. We did not see any significant order effect on the ratings of information sharing preferences with VIPs ($p-$ value=0.6104 with mean= 2.16 (VIP researcher) vs 2.08 (sighted researcher), Welch's t-test) and sighted ($p-$ value=0.8757 with mean= 2.47 (VIP researcher) vs 2.50 (sighted researcher), Welch's t-test). For both of the questions, we provided them a randomly selected category of publicly available information. Each participant only needed to respond to the subcategory of information in their selected category. The next two questions were open-ended and asked participants about what information they can share with VIPs and what information they don't want to share with anyone, including VIPs.

The next question in the survey gauged the preferences for sharing visually available information with VIPs:

> *Some visual information is already available to sighted people which might not be available to visually impaired persons. For example, a sighted person already knows your dress color, hair-level, your height, and other such information. Considering that the HoloLens wants to provide similar information to visually impaired people by capturing your image. How would you feel if the following information (that are already known by sighted people) is shared with a visually impaired person?*

Each participant received at most five items of visually available information to respond out of six categories. For this question, we also included the high-level categories of physical presence information: 'present nearby and visible' and 'present nearby and not visible' information. Finally, we asked our participants about their familiarity with HoloLens and their relationship with the device wearer. At the end of the survey, we asked the participants demographic questions. We also invited them for a subsequent interview study to shed further light on their responses.

4.1.2 Data Collection. In the paratyping study, we collected 62 responses from the five sessions. Four sessions were conducted in the researchers' work organization with 43 participants, where three sessions were conducted in the cafeteria (with 36 participants) and one session (with 7 participants) was conducted in a meeting room. Two sessions were conducted by a sighted researcher (both in the cafeteria) and the other two were conducted by the VIP researcher. The other session was conducted in the regular office area of the second organization with 18 participants.

4.1.3 Participants. From the 62 participants, we discarded the responses of one participant as the survey was incomplete. Among the 61 participants, we had 47 male and 14 female. Our participants came from a younger population (age range 25–40) with most being 25–30 years old (N=34). Most participants (N=42) had some level of familiarity while 19 participants did not have any familiarity with the HoloLens.

4.1.4 Ethical Considerations. Although we mentioned that the device is collecting information about the participants, we did not actually collect such information, primarily because real-time acquisition of such fine-grained information through face recognition on the HoloLens is still not a reality and second we did not need to collect any such data because this is just a paratyping study. When the participants returned the survey, we disclosed that we were not collecting any information from them.

Since we did not collect any personally identifiable information from the participants, our organization did not require the Institutional Review Board's (IRB) approval for this study. Nevertheless we followed strict procedures to maintain the confidentiality of participants, and convey the voluntary nature of the study. In the survey card, we informed the participants that by returning the survey they are giving consent to take part in this study. The nature of the participation was voluntary and the participants did not receive any compensation for taking part in the survey. As noted below, the interview based study did collect identifiable information (audio recordings) and needed IRB approval, which was obtained.

4.1.5 Survey Analysis. In performing analysis for the paratyping study, we focus on both average ratings and Indifferent Rate (IDR). The IDR is defined as the percentage of participants who reported indifferent or '1' on the 5-point Likert scales. IDR is opposite of Very Upset Rate (VUR) which is used by Lee *et al.* and Felt *et al.* [26, 48]. Both of the scales are helpful to understand the level of comfort of sharing information. Lower average VUR and Higher IDR on any information means participants are less hesitant to share the specific information.

4.2 Interview Study

As mentioned earlier, we invited our participants from the paratyping study to participate in a follow-up interview to gain deeper insights into their responses. Only six participants responded to our invitation. To get additional insights, we invited three other participants to participate in our study who did not participate in the paratyping study. For those three participants, we provided separate demonstrations where one researcher wore the HoloLens and walked around them when they participated. They did not fill the survey as we were asking similar questions in the interview.

In the interviews, we first showed the participants some examples of existing assistive technology. We described the capabilities of Seeing AI, Orcam [58], and HoloLens [36] to give them an indication of the possibility of such technology.At the beginning of the interviews, we asked basic demographic questions and asked about participant's feelings after seeing the researchers wearing HoloLens. Then, we asked their information sharing preferences in different workplace scenarios such as meeting room, one to one conversation, and cafeteria. We first invited open-ended responses and then we provided a list of information types. We presented all five categories of publicly available information and visible information, to understand their information sharing preferences. Finally, we explained the information sharing preferences regarding physical presence by presenting them with some hypothetical scenarios. In the interviews, we also explored the information sharing preferences regarding power relationships (such as a visually impaired boss) with the assistive technology user. The visually impaired researcher was not present during the interviews to reduce the social-desirability bias. All interviews were conducted by one researcher.

Our IRB approved the study and participants received a T-shirt for their participation.

4.2.1 Participants. Among the nine interview participants, we had five male and four female participants (age range between 18 to 30). All of them came from computer science related background. Our interviews lasted between 25 minutes to 40 minutes. The initial six interviews were conducted within one day to one week after the paratyping study.

4.2.2 Analysis. The interviews were audio recorded and later transcribed. The open-ended and interview responses were analyzed and coded using an iterative coding procedure with open coding. After each interview, two researchers discussed and identified concepts based on our research questions. Three main themes emerged from the initial interviews: Reaction, Preferences, and Control. The 'reaction' category covered the participants' reactions about using AR devices for VIPs and we had two themes under this category: positive and curious. The 'preferences' category covered participants' preferences over sharing their information and consists of eight sub categories: recipient type, information type, relationship with the recipient, availability of information, context of usage, consent, acknowledgement, and limitations. Finally, the 'Control' category covered how users want to control their information and has three sub categories: access-control, retraction, and user-based. After the first six interviews, we did not observe any new themes; still, we approached three other participants to check if saturation was reached. We did not find any new concepts in the last three interviews.

5 FINDINGS

In this section, we first highlight the information sharing preferences of bystanders with VIPs as compared to the sighted recipients. Then, we highlight the factors that may have influenced the information sharing preferences. Finally, we discuss the hypothetical boundaries of sharing information.

Table 1 summarizes the participants' reactions to the sharing of various publicly available information. Figure 3 shows the ratings distribution across different categories. Table 3 summarizes participants upset rating on giving their visible information to people with visual impairments. Figure 3f depicts the distribution of ratings across different types of visible information.

5.1 Information Sharing Preferences: Sighted vs. VIP Recipients

The main goal of this study is to explore whether sighted bystanders' information sharing preferences vary depending on the recipient type. Overall, we observed that participants are less hesitant to share information with VIPs as compared to sighted recipients. In response to their feelings regarding various types of publicly available information, participants gave lower 'upset' ratings (where lower ratings indicate a higher willingness to share)[6] to the visually impaired recipient (μ=2.12, σ=1.37) than the sighted recipient (μ=2.50, σ=1.48). As the same participants gave ratings for both types of recipients, we ran a Wilcoxon signed rank test to see if the difference is statistically significant. The test suggests that the differences in rating between VIPs and sighted recipients is statistically significant (V=342.5, p <0.001). If we compare the average ratings in Table 1, we can observe that in general, the rating is lower for VIP recipients. Figures 3a–3e clearly depict the preference, for most of the information types the ratings given to VIPs is less than the ratings given to the sighted people. Similarly, the IDR (indifference rate) is higher for VIP recipients. Only in one case (email in work-related information), we observed that the average rating is higher for VIP recipients than the sighted participants. However, the distribution in work related information (Figure 3d) seems similar and the higher average can be attributed to one participant's rating.

We also performed pairwise t-tests with Bonferroni correction on the overall differences of average ratings for each category and found that participants are significantly less hesitant to share their demographic, contact, and social media information to VIPs. The adjusted $p-$values are also reported in Table 1.

Although surveyed participants were less hesitant sharing their information with the VIPs, in the interviews almost all participants reported that they may not want to give extra privileges to a VIP. When we asked our participants about their information sharing preference most participants told us they do not differentiate between sharing information with the sighted persons and visually impaired persons. That is, they reported that if they can share any information with sighted persons then they can share the information with the VIP's as well. However, we checked the participants' survey responses and found that only approximately half of the participants gave the exact same scores for both VIP and sighted recipients.

To better understand this discrepancy, we looked at the specific categories of information. As can be seen in Table 1, if the information is semi-private (contact information, course grades, relationship status, work project information) then both the ratings and IDR are similar irrespective of the recipient. We used Spearman's

[6]Recall, the responses range from 1 ("indifferent") to 5 ("very upset").

Table 1. Participants' ratings for various publicly available information sharing.

		VIP recipient				Sighted recipient				
Information Category	**Information List**	**Average rating**	**Overall Average**	**IDR†**	**Overall IDR**	**Average Rating**	**Overall Average**	**IDR†**	**Overall IDR**	**Adjusted *p*-values on overall averages**
Demographic Information (N=9)	Name	1.33	1.61	77.8%	59.1%	1.67	2.31	66.7%	37.8%	**0.007****
	Exact age	1.55		55.6%		2.56		33.3%		
	Birthday	1.89		44.4%		2.56		33.3%		
	Exact height and weight	1.67		55.6%		2.11		33.3%		
	Picture	1.62		62.5%		2.67		22.2%		
Contact Information (N=11)	Name	1.09	2.87	90.1%	24.1%	2.09	3.5	45.5%	12.9%	**0.032***
	Address	3.27		9.0%		3.73		0%		
	Phone No	3.55		0%		4.36		0%		
	Email	3.18		9.0%		3.64		9.0%		
	Instant Messenger ID	3.3		10%		3.7		10%		
Work Related Information (N=10)	Name	1.3	2.05	80%	47.4%	2.0	2.41	50%	33.9%	0.16
	Basic work information	1.9		60.0%		2.33		44.4%		
	Work Hours	2.5		30.0%		2.8		10.0%		
	Project Information	2.2		40.0%		2.6		30.0%		
	Email	1.85		57.4%		1.71		71.4%		
	Past work history	2.5		20%		2.8		10%		
Education Information (N=16)	Degree title	1.5	2.01	75%	61.5%	1.68	2.13	56.3%	50.0%	0.6
	Educational Institute	2.0		68.8%		1.69		56.3%		
	Graduation Year	1.81		68.8%		1.88		62.5%		
	Courses Taken	1.69		75.0%		1.75		68.8%		
	Grades	3.25		25%		3.43		6.25%		
	Extra curricular activities	1.81		56.3%		1.94		43.8%		
Social Media Information (N=15)	Name/ID	2	2.11	40%	42.9%	2.4	2.50	33.3%	33.3%	**0.035***
	# of Friends and Followers	1.93		46.7%		2.33		33.3%		
	No./Name of Mutual Friends	1.8		53.3%		2.33		33.3%		
	Relationship Status	2.87		26.7%		3.4		20%		
	Political/Religious views	2.53		33.3%		2.87		26.7%		
	Recent Status	1.87		46.7%		2.13		46.7%		
	Hometown	1.8		53.3%		2.07		40.0%		

†IDR= Indifference Rate (Percentage of '1' on the 5-point Likert scales)

Statistical significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

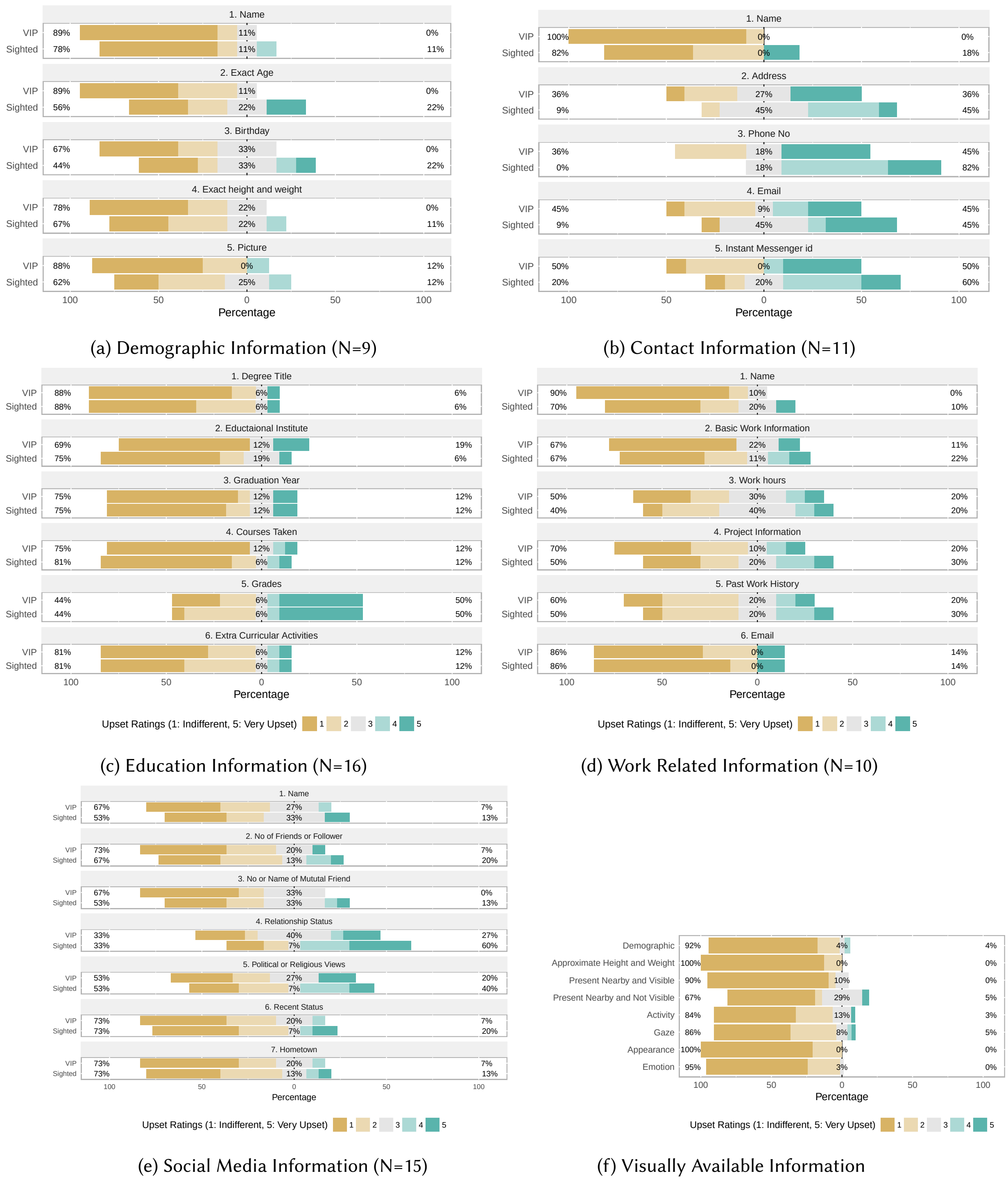


Fig. 3. Participants' upset rating for different categories of information

Table 2. Correlation between the sighted vs VIP recipient's score for different categories of information

Information Category	Spearman's Rank Test ρ	p-value
Demographic Information	0.63	$< 0.001^{***}$
Contact Information	0.77	$< 0.001^{***}$
Work Information	0.74	$< 0.001^{***}$
Education Information	0.91	$< 0.001^{***}$
Social Media Information	0.83	$< 0.001^{***}$

Statistical significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Rank Correlation test to observe the correlation in ratings in different information categories (Table 2). All information categories are positively correlated with education being the highest and demographics being the lowest (participants were more comfortable sharing demographic information with VIPs than with sighted people). Our findings suggest that people may be more comfortable sharing less sensitive information that are not available to VIPs (e.g. demographic), but not necessarily information that is considered more private.

When we sought the potential reason of not giving extra privilege to the VIPs, most participants expressed concerns about data misuse. P7 elaborately described his concerns as following:

> " *I mean it's another angle its okay if the visually impaired person might need more information to navigate. It's not as easy for him to reach somewhere. It opens up the same set of problems for like if a not visually impaired person picks up your device? You can't prevent that because the device is not specifically tuned to work only with visually impaired person. That's my concern. What if someone who is not visually impaired picks up this device. He might have extra information.*" (P7, Male)

With regards to the visible information and physical presence information, most participants reported that the information sharing should be equal regardless of the recipient. If the sighted people can see the information then the information can be shared with the VIPs as well.

5.2 Factors Influencing Information Sharing Preferences

From the responses, we noticed that various factors can influence information sharing preferences of bystanders in the context of assistive devices. In this section, we discuss these factors.

5.2.1 Gender. Koelle *et al.* reported that female participants are more likely to express negative feelings regarding the use of data glasses [41]. We also found that the gender of the bystander is also an important factor regarding information sharing with VIPs. On average, our female participants rated higher for the information sharing questions indicating that female participants (μ = 2.60) were more hesitant than the male participants (μ = 2.23) in sharing information regardless of the recipients. We found that the difference is statistically significant (t-test, p=0.0054). Even in the interviews it was clear that female participants were more uncomfortable sharing most information with both sighted and visually impaired individuals.

Although female participants were more hesitant regarding their information sharing preference, they were significantly ($t-$test, $p-$value=0.002) more willing to share information with VIP recipients (μ =2.23) as compared to sighted recipients (μ =2.96). Male participants were also more willing to share information with VIP recipients (μ =2.09) than the sighted recipients (μ =2.37) as well ($t-$test, $p-$value=0.02).

5.2.2 Interaction. In our interviews, we explored the relationship factor in depth. Some of our participants (P1, P6, P7, P8) reported that interaction before sharing information is important. After having a conversation with the VIP, people can share more information with them. Before initial interaction, they are willing to share some basic information such as name and basic work information but they reported that they would be more comfortable once an interaction occurs:

> "*Regarding what information I'd be comfortable giving it depends on how well I know the person. Suppose, there's a totally random person I do not know him at all, so I would not probably be comfortable with him finding out my name, my college degree, or collecting information from my social media profiles. But now suppose I know the person I have interacted with him before so depending upon the interaction, suppose I have met him and I have told him my name. Next time if he gets access to that information I wouldn't mind. So, I would prefer if the information sharing would depend on how well we know each other.*" (P1, Male)

Some participants (P6) reported that they would not mind even if the device records their conversation with VIPs and later analyzed it to extract information for subsequent use.

5.2.3 Power Relationship. We briefly explored the interaction between information sharing and the power relationship with the bystander. Interestingly, we found that participants are more comfortable sharing some publicly available information if the recipient is a visually impaired manager. The participants' rationale was, in the workplace the visually impaired manager should know about work-related information or education information. In case the visually impaired manager is not their immediate boss, they are still comfortable sharing information with the person because it may create new opportunities in the future (P9).

5.2.4 Available Information. Most participants reported that they do not mind sharing publicly available information except contact information. As can be seen in Table 1, most of the publicly available information received lower ratings or higher IDR. In the workplace context, the name is a publicly available information and our participants seemed comfortable sharing that information. We put 'Name' in multiple categories and in most categories 'Name' is the most acceptable information to share. Apart from the name, our participants rated some work-related information (basic work information, email) and educational information (degree title, graduation year, courses taken, extracurricular activities). In a workplace context, such information is usually made publicly available and this supports the comfort in sharing publicly available information. Conversely, the participants give a higher rating or are more upset to share more private information. Specially, participants were relatively more upset sharing their 'Contact' information with anyone. Although, some people share the contact information publicly, still they do not want to make this information available to anyone. In the interviews, some female participants said that the 'Contact' information is more likely to be misused and expressed negative feelings on sharing it. However, male participants gave slightly higher ratings (mean=3.3) compared to female participants (2.9) in 'Contact' information category. The difference is not statistically significant. Most participants reported that they do not mind sharing visual information or visible presence information with VIPs (Table 3). Since the visual information is already available to the sighted then the information can also be shared with the visually impaired.

5.2.5 Source of Information. The source of the information being shared is also an important factor in the context of sharing information with assistive devices. Most participants were hesitant sharing information from social media or other sensitive sources. We observed contrasting results for similar pieces of information. Only name and email were included in multiple categories. Although the IDR of 'Name' in demographics, work, and contacts category is above 75%, it is relatively lower in the social media category which depicts participants' discomfort of fetching information from social media. Similarly, the indifferent rate of email is relatively lower in the contact category than the email in work category.

In case of physical presence information, we also observed that the source of information can cause discomfort. The main concern is if the data comes from a controversial or sensitive source then the data can be misused. Although, some people do not mind sharing their presence with a coworker they were uncomfortable if the presence information comes from a tracking device. If their location is tracked by CCTV cameras or GPS then the participants reported that they will not be comfortable sharing this information with a visually impaired co-worker.

5.2.6 Context of Usage. As reported by both Koelle *et al.* [41] and Denning *et al.* [22] information sharing preference depends on the context of usage. If VIPs use it for improving their accessibility to information or independence, then some people (potential bystanders) don't mind sharing it. Participants are comfortable sharing even more information if it helps people with visual impairments. For example, participants (P6) said that if their presence in their workstation helps the VIPs to reduce their effort then they don't mind sharing it:

> "*If it's too much effort, and it's not very easy like a sighted person then fairness comes into play there. For a sighted person, it is easy to look up the desk to check if the person is there or not. For a visually impaired, the amount of effort to do the same activity might be much more. Then, in that sense it's okay to give information of the person is present in the desk or not.*" (P6, Female)

Moreover, some participants also reported that if the data is not used to judge them then they don't mind sharing it. From the publicly available information, participants were more comfortable sharing their demographic information with the visually impaired than the sighted. This preference implies the bystanders' understanding of the lack of information available to the visually impaired and they seem comfortable sharing such information with the visually impaired to fill the gap.

5.2.7 Control, Consent, and Acknowledgement. Our participants reported that consent is important before sharing certain types of information. Our participants (as bystanders) expressed they would like to be able to give their consent when assistive devices collect and share publicly available information with VIPs. Further, they also expect to be informed about the nature of the data being shared to enable them to act appropriately. For example, in the cafeteria situation, if they do not want to be noticed by a sighted colleague they may sit behind a partition. However, if they know that their presence will be made known to VIPs and they have given their consent for it, then they have to take other measures if they do not want to be noticed by the VIPs. Schlegel et al. also found that conveying 'exposure' information about location accesses was beneficial in location-sharing applications by creating an awareness of who is accessing one's information and providing controls for improved privacy [67].

The consent and acknowledgement process can be made straightforward by giving control to the users. Our participants repeatedly discussed about the importance of having some control over their publicly available information. They would like to be able to control what information is being collected and what information is going to be shared. If some information is already public, then the user should be able to revoke the access. The request for control can be easily understood by the following commentary:

> " *What I want is mechanism which would let me control the information that I can share with the device. If I am comfortable sharing my age, I might share that. There must be basic information that is always public just like Facebook may be picture and my name. If I want I could have everything else hidden. I could have my friend circle or trusted circle accessing this information. I want some control which is relevant and authorized information. I should be able to whatever information I made public can be made private. It should be no longer accessible, although it was public at one point of time.* "(P8, Male)

In case of visually available information, it is not important to ask for consent before sharing that information to the visually impaired (P5, P6, P7, P8). However, it is important for the participants and bystanders to know how they are being presented and they should be able to control this representation. For example, if the system is inferring a 20-year-old person as 50 years old, the participants might feel uncomfortable and may decide to not share their age. Most participants do not want to share information if recipients are not visible in the vicinity because, e.g., one's gaze provides a signal to the bystander that the other person is looking at them and potentially acquiring information about them. We discuss some more subtle aspects related to sharing of visually available information in the next section.

5.3 Boundaries of Sharing Available Information

The factors associated with information sharing could be helpful to define the hypothetical boundaries with regards to sharing different kinds of information. In this section, we discuss some rules to define the boundaries regarding sharing public, visual, and presence information.

5.3.1 Public Information Should Be Accessed after an Interaction. As discussed in the previous section, an initial interaction is important before sharing the publicly available information. Therefore, assistive devices can retrieve some publicly available information after an initial interaction. The participants even provided some great suggestions and options to share their publicly available information after initial interaction:

> "*If we were meeting for the first time, you don't know my educational background, just as it is. I don't know why a visually impaired person should know that. [Giving extra cue to remind you?] Um, there are two cases. One where it's like a reminder sort of a thing. It's not the first meeting, I have already introduced to you. Or may be there can be approval or agreement kind of a thing. After I met you, you can get all the publicly available data about me. It can be fed after my consent. Next time when you meet me, it's okay to recall that you have met this person here, then giving some educational background should be okay. But, it's just you have the publicly available information and there are people in the corridor and you get information about everybody, that's a bit scary.*" (P6, Female)

As P6 mentioned, some publicly available information can be made available after initial interaction. People have control over their publicly available information and can be made private anytime. Some participants discussed of having a public profile (P8), from where the such assistive system will collect information periodically. That information can be made available to VIPs after an initial interaction.

5.3.2 Public Information Should Be Controlled by the User. Although it is easy to find information about people by performing a simple search, it takes some effort which creates a 'barrier of privacy'. Assistive devices or AR/VR devices should not make it so accessible that average user can easily access this information:

> " *From my perspective I'm not really comfortable even if my information is public. A lot of my information is public and a lot of that it's not intentional. A lot of information is leaked like a lot of things that I do on Facebook is supposed to remain within my friend group but is it leaks easily. The easier it is to find the public information the less secure I feel. I mean I know it's possible but then there's always a barrier I mean your average day Joe can't do it . If it becomes so and so easier, then it does feel invasive.* " (P7, Male)

The devices should not eradicate the barrier, instead there should be some controls to the user:

> "*Someone somewhere who knew my birth date might have wished me on Facebook publicly, so indirectly my birth date is out there. That's not my intention, I never wanted that with it. But I can't do anything about it now, so there I want some barrier for if someone wants to go and fetch that information it's not like you'd run an AI search and it will be able to figure that out easily. I don't want that, that barrier should exist. The person should go to my profile scroll down five years of posts and figure that out. So if*

Table 3. Participant's' average rating and IDR on visual information which is already available to sighted people.

Information Category	Average Rating	IDR
Demographic (name,age,gender)	1.35	76.9%
Approximate Height and Weight	1.12	87.1%
Gaze	1.68	54.1%
Activity	1.63	57.9%
Appearance (dress color,type)	1.21	78.9%
Emotion (tired, stressed, happy, sad)	1.38	71.8%
Present nearby and visible	1.23	85.7%
Present nearby and not visible	1.81	61.9%

the information is leaked somewhere, I want a barrier to exist. If information is public by my own accord like for example my designation or my name then its fine." (P7, Male)

These suggestions are in line with Nissenbaum's observation that even if information is technically available, a change in the information dissemination norms can cause privacy harms by violating 'contextual integrity' [57].

5.3.3 Visually Available Information Should Also Be Limited. The factors associated with sharing publicly available information also applies to visually available information. Most participants do not mind sharing the apparent information to people with visual impairments which can be seen in Table 3. The most comfortable category for recipients is approximate height and weight, demographics, appearances, and visible presence information. The comfort of sharing demographic information is also apparent in Table 1 where we can see the clear distinction in ratings and IDR with sighted recipients. On the contrary, we can see that gaze, activity, and invisible presence information are slightly more discomforting than the others. The distribution of ratings (Figure 3f) depicts that although most participants are comfortable, some participants have discomfort regarding sharing this information. Most participants expressed concerns on giving extra information regarding visible information. Therefore, visible information should also be limited, especially for information about gaze, activity, and presence (when not visible to a sighted individual). The detailed concerns and comments are presented in the following sections.

5.3.4 Visual Information Should Be Accessed through Natural Vision. In our interviews with the participants, we explored various edge cases of visual information sharing. Most participants (P4, P7, P8, P9) discussed that only the kind of information that can be accessed through natural vision should be shared. Sighted people have around 120 degrees of peripheral vision, and assistive technologies should also access a similar field of view.

" *[Knowing information from back] .. that is too much information. So if I have three people sitting at the back, I don't know who they're; I don't know what they're doing. So, if I am the boss like and those are my juniors, they could be doing random stuff. If they know that I'm actually I can always detect what they're doing, that's create an weird environment. It's an unnecessary constraint, plus those people will feel uncomfortable and probably think that this guy has the eye on his back literally. So your field of vision should be the same as what a sighted person should have.*" (P7, Male)

5.3.5 Information Should Be Accessed through Natural Interaction. Some participants felt that information that is not available through natural vision, should be accessed only through natural interaction. For example, in the meeting room, if people want to know a bystander's activity or gaze, the user (VIP) could look towards them. Participants suggested the user should not get information that is not natural, such as getting information about a person when not looking at them. In a conference room, people act differently if somebody is looking at them. People respond differently and the reaction depends on the relationship with the person looking. So, directly looking at someone gives the bystander a signal and they respond appropriately (P4, P6, P8). Accessing information without such 'social signal' could be discomforting for the bystanders. Therefore, in social contexts, these types of signaling are important and only natural interaction can give similar signals and maintain the norms of information collection so as to not violate contextual integrity. P1's commentary discussed the necessity of natural interaction in his commentary:

> "*Suppose you are giving a presentation and I should ideally be focusing on you. Suppose now you yourself are looking at some place and I just I also let go of the information of my attention, so you would not probably find out and I know that you won't find out. Hence I'm okay, I can do that stuff. Now suppose there's a machine looking at me so I know that I have to pay attention otherwise it'll alert that person. probably I would not want that irrespective of whether the person can see or not. It's like anything the normal person information that he can get should can be very easily be accessible to the visually impaired person also. So, like gaze if you wants to know where am I looking at some particular point of time , it's okay. But it should not be like you should be alerted every time that I'm not paying attention. So like natural, so whatever the natural human capacity is that part should be accessible to that.* " (P1, Male)

5.3.6 Only Visible Presence Should Be Provided. Tracking is uncomfortable to most participants (N=6) and might cause discomfort especially in the context of CCTV cameras or GPS to locate people. Even though participants were supportive of providing such information, they worried about what kind of tracking system might implement such functionality. Some participants (P2, P5, P6) considered the accessibility issues of VIPs and mentioned that they could share some form of binary presence information, perhaps through alternative sensors. For example, they could provide information about whether they are present at their desk using a lower-fidelity sensing mechanism. In particular, participants did not want to share their exact locations with VIPs.

5.3.7 Bystanders Should Be Informed. As mentioned earlier in the context of 'exposure awareness' [67], although most information in our everyday environment is visual and sighted people already know this information, bystanders should be informed that assistive devices share some visible information like their activity, gaze, and emotion. It is not necessary to ask for a bystander's permission; providing a signal, however, to the bystanders that visually impaired people might have access to such information might be acceptable.

An important scenario mentioned by one participant (P4) was that the VIP may not even be interested in knowing about P4, but their device might push information about his mood to the VIP. Normally a sighted person may not have noticed this, and a VIP now may have access to additional emotions (that the VIP didn't necessarily care about):

> "*Let's say, I'm a bit sad or I'm thinking about something and I'm bit tensed. So I know that you are not noticing me but a visually impaired person is noticing is seeing me but I know he is visually impaired. But his hearing device that is noticing all these things and it is it means it figured out that I am a bit tensed about something, so that's kind of complex scenario.*" (P4, Male)

Some participants also felt that people assume VIPs cannot see certain things and need to be informed if this is now possible. Although having such information suddenly available to VIPs is indeed a violation of contextual integrity (a departure from how information is normally (un)available to most VIPs), it is important that bystanders become normalized to the availability of such information to VIPs through assistive devices.

We also note that such additional information would be available to sighted recipients as well, and would also constitute a violation of contextual integrity, where a sighted recipient not looking at an individual may receive information about their expressions. However, we expect such concerns to be heightened (at least initially) because of the current assumptions made about VIPs and what information is typically available to them.

6 DISCUSSION

In this work, we extended the previous line of research in the context of bystander's privacy related to wearable devices. We specifically focused on the privacy issues of sighted bystanders in the context of assistive device usage. Although Google Glass faced significant backlash due to privacy issues, Google glass seemed to have a positive influence on the accessibility researchers. Various solutions [9, 27, 68] were motivated from the Google Glass based services and it seems to have a positive impact on VIPs. The contrast between the privacy issues and accessibility problems motivated us to explore this problem. In this study, we found that participants' preferences vary with the recipient types; people are less hesitant to share information with VIPs than sighted. However, participants are more comfortable sharing those information that are already available to sighted but not available to the VIPs. They are more inclined to give 'equality' than 'equity'. Our study also identified several factors that were also reported in previous studies. For example, both Denning *et al.* [22] and Koelle *et al.* [41] reported the importance of 'context of usage' in sharing decisions. Koelle *et al.* [41] also reported the effect of gender on sharing information. Our study confirmed some previously identified factors as well as discovered some new factors that may influence user's decision on information sharing such as initial interaction and source of information. We also identified that relationship with the device wearer also plays a role.Apart from the factors, our study also identifies some ethical boundaries regarding the information provided to the VIPs.

6.1 Limitations of the Study

One limitation of our study is that participants answered questions about hypothetical behaviors, i.e., their potential sharing preferences with VIPs. In particular, their responses could reflect a social acceptability bias, where they declare preferences that are more socially acceptable rather than how they might behave in real life. Although further work is needed to observe the actual behaviors and preferences of bystanders in the context of real-world use of augmented reality devices, future work should consider more nuanced questioning of participants. For example, our question "How would you feel if the following information (that are already known by sighted people) is shared with a visually impaired person?" could be improved to include a spectrum of viewpoints (e.g., how "some people do not mind sharing such information whereas some may have privacy concerns") and asking where the participant sits on that spectrum and why. Such opposing viewpoints could help avoid a social acceptability bias.

Our findings should also be contextualized within the frame of reference presented to participants. Although AR glasses and the HoloLens may be used in myriad ways, we focused on a scenario based on our assistive application, which raises more privacy concerns than other scenarios related to how such devices might be used in practice. Still, our questions related to information sharing preferences are focused on such privacy-sensitive information and our findings are applicable to the narrower context of AR applications making use of such information.

Although we specifically study the workplace context, we must bear in mind that participants were technology aware, typically in the age range of 24–40 years, and comfortable with social media. In addition, the culture of the participants was also that of a cosmopolitan city dweller based on the location of the study.

Finally, we study the comfort levels of sharing various types of information but in this study do not consider the implications of information that can be implied or inferred from other information. Instead we seek to directly understand the comfort levels of revealing the specific types of information. One way of interpreting these results it that if certain information can be inferred from other revealed information, our data indicate the comfort levels if individuals were alerted to the possibility of such data being leaked/revealed.

6.2 Studying Other Contexts

The present study was conducted in technology aware workplaces to study one specific context of information sharing. Each context will have their own norms of information sharing, and departures from these norms can result in privacy harms because of a violation in 'contextual integrity' [57]. For example, if the context is switched to public spaces the concerns and preferences are expected to be different. Thus our research motivates similar studies in these different contexts as the next step. However, even within the workplace preferences can be contextual and information sharing might depend on the specific goals to be accomplished. For example, bystanders in the workplace may be more willing to share presence information with a VIP in a supervisory role during work hours, but less willing during non-work hours.

Future work could include public contexts such as shopping areas and restaurants and other organizational or workplace contexts such as university campuses. Given that there is a distinct shift towards ubiquity of such technologies, it is important to understand the nuanced privacy concerns in diverse environments. We believe that ours is the first of many more studies that are needed to fully understand the implications of such technology, and we hope our research spurs further investigation on information sharing preferences in varied contexts.

6.3 Studying VIPs as Bystanders

We have presented the results of our paratyping study to understand the information sharing preferences of *sighted* bystanders in the context of assistive technologies worn by VIPs in workplaces. In our study we asked *sighted* bystanders about their relative comfort levels for both sighted and VIP wearers of AR technologies. As mentioned in the Introduction, we assume that VIP wearers would be more willing than sighted bystanders in assisting other VIPs, although this intuition should be substantiated in future work. Furthermore, it would be interesting to see to what degree VIP bystanders are more (or less) willing to share information than sighted bystanders. Finally, in the larger context of wearable technologies, it would be interesting to understand the information sharing preferences of VIPs with sighted wearers of AR.

6.4 Privacy Issues of Crowdsourcing Based Assistive Services

Privacy issues of bystanders are already apparent in current crowd-based assistive services. For example, TapTapSee [69] is an app that uses crowdsourcing to inform VIPs about the contents of photos taken by the user. Private and sensitive information may be presented to a remote stranger without the knowledge or consent of the persons in the picture. A more recent example is the service Aira [9] in which the VIP sends a live stream of video to a crowd-worker for remote assistance. Aira states in its privacy policy that up to 18 months of recordings are used for improvements made to their service and includes "information shared by others (including who transmit information about you during a Session)" [8]. Although our work focuses on the use of information by VIPs, the findings of our study raise similar privacy issues for such services. Future work could study privacy issues of bystanders by also considering how the service provider handles data. For example, a coworker might feel uncomfortable if an image of them is analyzed by a crowd-worker as opposed to an automated algorithm.

6.5 Towards Achieving Equity for VIPs

As discussed in the Introduction, our overall premise is that VIPs should attain equity in the workplace, and the information asymmetry of what is available to sighted persons as opposed to VIPs is one opportunity to achieve equity. In general, more work is needed to provide a holistic answer to the question of what is needed to achieve equity; in this paper we focus on what can be addressed in terms of information that can be made available to the VIP.

Although we found that sighted bystanders are more willing to share information with VIPs as compared to bystanders, there will certainly be people who do not wish to assist people with impairments. In either case, bystanders could be induced to share even more information with VIPs. For example, some of the participants in the interview were willing to share more information with VIPs once they got to know the person. This clearly points to the dynamic nature of such information sharing preferences, and mechanisms and social interaction that might induce more sharing of information with VIPs. We leave such explorations for future work. We found that bystanders were not always willing to share 'more' with VIPs. In the case of more private information, bystanders were equally likely to share information with VIPs and sighted people. Thus more work remains to be done in the context of 'equity', as our findings indicate that when bystanders are asked to articulate their sharing preferences they take more of an 'equality' frame of reference.

This general line of work also raises ethical questions about 'ableist' bystanders who may question whether or to what degree the (additional) information needs of VIPs should be taken into account. In general, one might ask at what point does technical power available to disabled users supersede what others have, and is that acceptable to others? The knowledge of such concerns even in a restricted workplace environment is important both to design such technologies to allay these concerns and more importantly to educate and sensitize sighted bystanders about their (unconscious) discrimination that such concerns demonstrate. If such concerns are not understood and addressed, negative reactions might push back the deployment of such technologies at scale, and may prove even more harmful to VIPs if deployment is stalled. There are several examples where society strives to provide 'equity' to people with disabilities, e.g., parking spots exclusively for the disabled are located closer to building entrances than general parking and students with test anxiety are given extra time on exams. Although some debate around such accommodations is to be expected (e.g., there has been debate about whether metered parking spaces should be free for the disabled [12, 24]), some have proved controversial questioning at what point 'equity' is surpassed: when four Paralympic runners beat the timing of the Olympic winner for the 1500m event it raised questions about whether Paralympic athletes had been given an unfair advantage [21, 31].

The 'equity vs. equality' debate in the technological domain, however, raises interesting questions. Unlike the previous examples, technology based assistive technologies are not limited to be used exclusively by people with disabilities. Augmented reality based solutions, e.g., may be in use by both sighted as well as VIPs, and enhance the capabilities of both parties. In this case, the question then focuses on the nature of the information differential between what should be available to sighted people vs. VIPs. And furthermore, what information would people be willing to provide each other as users and bystanders of the same technology? As one might expect, bystanders may be willing to share additional information, but only 'up to a limit'. Our findings indicate that with familiarization and control bystanders are indeed more comfortable with giving extra information to people with visual impairments depending on the nature of the information. In general, we feel additional research is needed on this debate; unlike in the case of Paralympic athletes, which is a highly regulated and monitored environment, the use of assistive technology — not exclusively by people with disabilities — in unregulated, everyday environments raises interesting questions about information exchange and equity that need to be further understood.

6.6 Opportunities for Access-Control Mechanisms

An important finding from this study is that most participants want to control the nature and type of data depending on the context and individuals with whom such data is shared with. Another important factor on the minds of participants is the misuse of technology by those other than the intended users. Hence authentication mechanisms should ensure that only the wearers verified to have an impairment is given access to the information.

Such control could be easier to provide within organizational contexts since the organization can verify and authorize users with impairments.

We found that given control and knowledge of what is being shared, the general discomfort about sharing information appears to diminish for most participants. Based on this finding we believe that there is a need for research on specialized access-control mechanisms for automated information sharing through assistive technologies, specifically in the workplace context. Our participants briefly discussed some suggestions for access-control policies that can help VIPs while balancing the privacy of bystanders. The access-control policies can be permission-based or form-based where people can check what these assistive devices are collecting and can allow or deny access based on their level of comfort. P5 suggested an interesting way to provide some level of additional information to VIPs: people can provide a short summary on their work profile, which can be accessed by (authenticated) assistive devices. There can be two benefits for such an approach: bystanders can easily limit their information in general and VIPs can specifically obtain pertinent information in the context of assistive devices. Access-control policies can be role-based or context-based, where different levels of information can be shared depending on the roles or contexts.

Understanding and exploring effective access-control policies need to be explored in the future. We expect such access-control mechanisms will help provide flexibility and hence make the workplace more accessible to VIPs since more data will be available for sharing without reservations since the sighted participants are making such data available under their own control.

6.7 Challenges when Relying on Technology

Vision based tools are not always accurate and VIPs may put too much trust in computer-generated information [50], and furthermore bystanders might feel uncomfortable being misrepresented to VIPs. For example, if a VIP is told that a person is about 25 years old, while the person is actually 50, there are two issues: the VIP will be working under the wrong assumption. Second, the person whose age was reported as 25 may not appreciate being portrayed as a younger person. Also consider whether a system can confidently describe an individual as "a 25 year old man looking happy" with no way to verify if the man is indeed 25 and indeed "happy". Furthermore, the gender identified by the system may not match the gender with which the bystander identifies. In general, such technology needs to be mindful of myriad issues related to the portrayal of emotions, relationships, race, ethnicity, gender, age, and so on. We have not addressed such issues in our study but they need to be addressed in future work. As one possibility, access-control policies not only can control *what* information is being shared but also potentially *how* the information is being shared. If the bystander does not like their representation they can choose to disclose accurate information or can deny providing such information.

Other issues related to the use of technology include the potential for social isolation — whereas bystanders may have helped VIPs through social interaction, with such technologies bystanders may reduce their interactions in a 'caregiver' role. Interestingly Lorenzen-Huber et al. found that assistive technologies in the context of in-home caregiving for elders did *not* decrease in their study [49]. On the other hand, the use of assistive technologies can also create social stress [47] by calling attention to one's disability and raising concerns about the 'equity' debate discussed earlier. We hope our work inspires future work on both improving the acceptance of such assistive technology through a holistic approach considering a host of social issues including privacy.

7 CONCLUSIONS

While modern assistive devices offer new functionality for VIPs, the information collected and shared by these devices has an impact on the bystanders who are 'analyzed' by such devices. In our study, we tried to understand the impact, concerns, and reactions of the bystanders when sharing information with VIPs. Our study suggests that bystanders are willing to share *more* information with VIPs as compared to sighted users of AR applications.

We found that participants are willing to share even more information with VIPs with better access control mechanisms, especially when they are provided assurance that their information will be used for assistive purposes. In our study, we found factors like the context of usage and initial interactions are important for information sharing. Based on the factors, we also tried to find some rules which will motivate the researchers to understand the bystanders' perspective regarding their information collection and creating better access-control policies to aid VIPs.

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