How Users, Facility Managers, and Bystanders Perceive and Accept a Navigation Robot for Visually Impaired People in Public Buildings

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***Abstract*— Autonomous navigation robots have a considerable potential to offer a new form of mobility aid to people with visual impairments. However, to deploy such robots in public buildings, it is imperative to receive acceptance from not only robot users but also people that use the buildings and managers of those facilities. Therefore, we conducted three studies to investigate the acceptance and concerns of our prototype robot, which looks like a regular suitcase. First, an online survey revealed that people could accept the robot navigating blind users. Second, in the interviews with facility managers, they were cautious about the robot's camera and the privacy of their customers. Finally, focus group sessions with legally blind participants who experienced the robot navigation revealed that the robot may cause trouble when it collides with those who may not be aware of the user's blindness. Still, many participants liked the design of the robot which assimilated into the surroundings.**

I. Introduction

People with visual impairments (PVI) face significant challenges in walking through large and complicated public buildings such as shopping malls, airports, and hospitals, due to their lack of vision. Autonomous navigation robots have a considerable potential to transform the daily lives of PVI by allowing them to walk independently in such spaces. Recent research has proposed navigation robots that can guide PVI to their destinations and help them avoid obstacles and nearby pedestrians [1], [2].

To deploy navigation robots in public buildings, it is imperative to obtain acceptance not only from robot users but also bystanders in the buildings and managers of those facilities. Specifically, 1) a navigation robot needs to be socially accepted by the public, 2) a navigation robot used in buildings needs to be accepted by facility managers because they are responsible for keeping the buildings safe, reliable, and enjoyable for everyone, and 3) a navigation robot needs to be accepted by its users. Prior studies have investigated the social acceptance of assistive technologies, including wearable cameras [3], [4], [5] and computer vision-based assistance [6], [7], with the PVI and the bystanders. However, there are limited studies on the acceptance and concerns of navigation robots for blind people [8], and no study has investigated it with facility managers.

We conducted three studies to investigate the acceptance and concerns of three stakeholders: 1) an online survey of the public, 2) interviews with facility managers, and 3) focus groups with legally blind people. We used a prototype navigation robot assembled into a suitcase, which can assimilate into the environment[1]. It was able to avoid obstacles and pedestrians while navigating the users in multi-story buildings.

We first conducted an online survey with 300 sighted participants, focusing on the social acceptance of our navigation robot. Because our prototype robot was different from autonomous service robots such as security and delivery robots, we created two types of videos that showed the behaviors of the robot: One showed the robot guiding a user, and the other showed the robot moving about alone. The results revealed that the participants felt significantly more comfortable, less obstructed, and safer with the robot guiding a user than with the robot moving about alone. We also observed that many participants would accept being captured by a camera if the data were used for assisting PVI and would not be saved.

In the second study, we interviewed 15 facility managers from 6 entities, including 3 retail stores, 2 medical facilities, and a museum, regarding concerns that may arise when introducing robots to their buildings. We showed them the videos and observed that managers expressed concern that surrounding people might misunderstand the purpose of the robot's camera, which could cause privacy-related issues. They also commented that the movements of the robot were so natural that the user would not seem PVI, and thus, we may need some way to indicate that the users are PVI. In this paper, we define these concerns as **"privacy concerns"** and **"visibility concerns"**, respectively. We discussed these concerns with blind participants in the focus group session.

In focus group sessions, we asked 12 participants who are legally blind to use our robot in an office building and then discussed concerns that may arise upon using robots in public buildings. While all the participants appreciated that the robot's design looked very natural and cool, they shared various opinions regarding their concerns with its appearance. Five participants commented that they prefer not to be recognized as PVI, but seven participants agreed with the visibility concerns and suggested informing surrounding people that they were PVI. Regarding privacy, while six participants did not mind capturing people in the surroundings with a camera on the suitcase, the others were concerned that they might get into trouble if people misunderstood the

[1]Waseda University
[2]Miraikan - The National Museum of Emerging Science and Innovation
[3]Carnegie Mellon University
[4]IBM Research
[5]Waseda Research Institute for Science and Engineering

[1]https://github.com/CMU-cabot/cabot

purpose of the camera.

Based on the results and findings of the three studies, we analyzed the convergent and divergent opinions among blind users, facility managers, and bystanders. In the discussion section, we further discuss how to reduce privacy and visibility concerns in addition to safety considerations.

II. Related Work

A. Social Acceptance of Assistive System for PVI

Koelle *et al.,* defined social acceptability as "A human-machine interface can be considered socially acceptable, if its presence or the user's interactions with it are consistent with the user's self-image and external image, or alter them in a positive way" [9]. Several aspects influence the social acceptability of assistive technologies for people with disabilities: these include functionality appearance, privacy, and security. Studies reveal that technologies that are conspicuous, unusual, or non-mainstream appearance could leave many users feeling deviant, stigmatized, and otherness [10], [11], [12]. Although image recognition technology is a promising way to help PVI, it leads to privacy and security concerns for their users [7] and the bystanders being captured [4], [13]. A few studies have investigated how people are willing to be recognized by or share their information with the technologies that help PVI [3], [5], [6]. These studies showed that people feel more comfortable to be recognized when they are aware of users' disabilities which Profita *et al.,* named AT-effects [3].

PVI want the assistive robots without looking awkward, but discreet, inconspicuous, and safe [14]. An interesting exception is reported by Azenkot *et al.,* [8], in which their design team, including members with visual impairments, agreed that function was more important than form. The authors explained that their designed robot is not a personal device but resides in a building. Still, they wanted the robot to act socially, such as flowing with traffic and avoiding actions that were disruptive or attracted extra attention.

B. Social Acceptance of Autonomous Robots

There is a large body of research investigating and discussing the social acceptance of service robots [15]. Such service robots have become part of work-life in many sectors [16]. Studies have investigated the social acceptance of public relations robots [17], security robots [18], delivery robots [19], and healthcare robots [20]. Similar to the previously introduced assistive technologies, service robots involve multiple stakeholders. Niemela *et al.,* studied the acceptance of social robots in a shopping mall of their customers, store managers, and mall managers [17].

Compared with the existing autonomous service robots such as security robots and delivery robots, navigation robots guiding PVI are characterized by the fact that the user always moves beside the robot. Thus, we conducted an online survey with sighted people, where we compared the social acceptance of the robot guiding a user and the robot moving about alone.

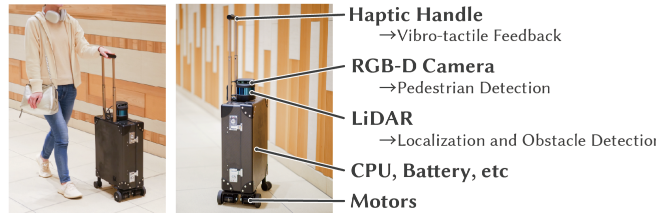

Fig. 1. Our prototype navigation robot.

C. Navigation Robots for PVI

Previous research and commercial solutions have presented various navigation systems for PVI through mobile phones, smart canes, wearable devices, and robots [21]. Navigation robots have the potential to improve the mobility and independence of PVI. Navigation robots can guide PVI while avoiding obstacles and passersby in the same manner as guide dogs [1], [2], [8], [22], [23], [24], [25]. Users can perceive and follow changes in the direction of such a system. Guerreiro *et al.,* proposed an autonomous navigation robot that can guide PVI to their destination while avoiding obstacles on their path [2]. PVI follow the robot by holding onto a handle, which can actively guide and influence the users' trajectory.

Prior works focused on proposing new autonomous navigation robots and evaluating systems only with blind users (*e.g.,* their ratings of confidence, safety, and trust [2]). However, for robots to gain widespread acceptance by society, it is essential to explore how not only robot users but also facility managers and the public would accept robots in public spaces. Thus, we investigated the social acceptance of navigation robots in public buildings by conducting an online survey of sighted people, interviews with facility managers, and three focus groups with legally blind people.

III. Implementation of Autonomous Robot

We designed a navigation robot with reference to prior studies [1], [2], [8], [14] and tested it in large and crowded multi-story buildings (a five-story shopping mall building and selected floors of a 25-story office building). The robot's source code is available on a public repository[1]. We designed the robot based on the following principles: **1) The robot considers the user who holds its handle as much as possible**: The navigation robot walks alongside the user, so it needs to consider not only its body but also the user's body to compute its path and speed [2]. **2) The robot follows social norms in the building as much as possible**: The robot must consider nearby pedestrians on behalf of the user. The robot recognizes people in the surroundings so that it and the user can behave socially; avoiding people standing still, following people walking in front of the robot, social distancing, navigating through elevators, and waiting in lines [8]. We implemented functionalities in addition to the existing navigation robot [2], [1], including high-precision localization, social-aware navigation (*e.g.,* queuing and floor transitioning using elevators), and a smartphone app

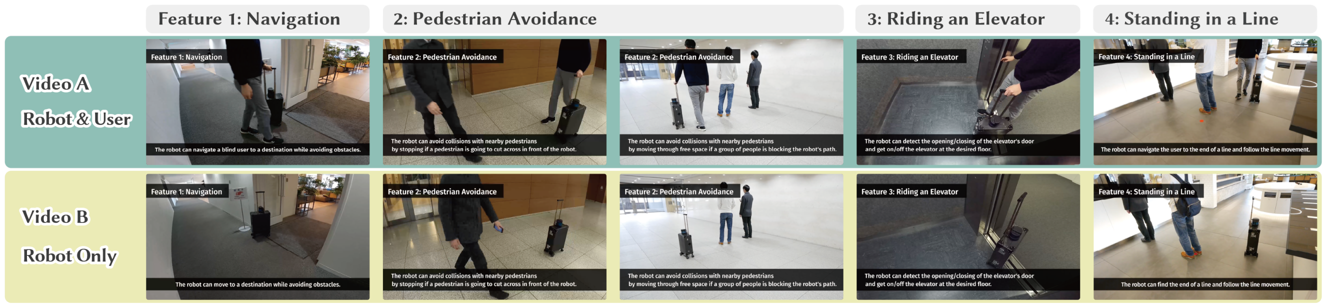

Fig. 2. Video stimuli used in our online survey. While the two videos presented the robot's features from the same place, same camera angle, and with the same movements, video A shows the robot assisting a blind person, and video B shows the robot moving about alone.

to control the robot. The robot was assembled in a ready-made suitcase (Fig. 1), which enables the robot to blend with the environment without attracting much attention [14]. The suitcase handle provides vibro-tactile feedback about the robot's directional actions [2].

The robot utilizes radio frequency signals like Wi-Fi or Bluetooth to approximately localize its location in large multi-story buildings. It also uses a LiDAR sensor to localize its position and orientation in a building by matching point clouds to a pre-built map to get the location within several inches' precision. The robot can detect and track surrounding people with its RGB-D (RGB image + depth) camera and estimate the status (position, speed, walking direction) of each person. It recognizes people in an image by using Yolo V4 [26] at a rate of 10 frames per second, and it behaves socially based on the recognition results. It keeps social distance as much as possible, avoids people standing in its path, and waits in lines. The robot can also navigate through elevators with minimal help from the user. It asks users to push the elevator buttons by indicating in detail the location of the buttons to call the elevator.

IV. Online Survey of Bystanders

We first evaluated the social acceptance of the navigation robot with online sighted participants. The main research questions of this online survey were **"how will bystanders accept our robot moving about in public buildings"** and **"how does social acceptance varies between the robot guiding blind users and the robot moving about alone"**. We recruited more than 300 participants via a crowdsourcing marketplace[2] and asked them to answer our questions after watching the two videos that presented the features of our robot. The videos and the list of all questions are available on our web page[3].

A. Video Stimuli

Participants watched two videos (Fig 2): video A, which showed the robot guiding a user with a blindfold, and video B shows the robot moving about alone. Both videos had the same content and present the robot's four features: **1) Navigation:** Navigating users to their destinations while avoiding obstacles. **2) Pedestrian Avoidance:** Avoiding collisions with nearby pedestrians by stopping when a pedestrian walked across in front of the robot or by moving through free space when a group of people blocked the robot's path. **3) Riding an Elevator:** Detecting the opening/closing of an elevator door and getting on/off the elevator at the desired floor. **4) Standing in a Line:** Navigating the user to the end of a line and following the line movement. The two videos presented these features from the same place, same camera angle, and with the same movements. The only difference between the two videos is that one has a user next to the robot while the other does not.

B. Procedures

On the instructions page, we first mentioned that our survey contained secret questions for determining compensation to encourage participants to answer all the questions thoroughly; it was adapted from a performance-based payment approach [27]. Participants watched either video A (robot and user) or B (robot only) and answered questions about the social acceptance of the robot presented in the video. After completing the questions, they watched the other video and answered the same questions again. The order of videos to be watched was randomized for each participant.

Three secret questions (one in video A and two in video B) that we asked to check whether the online participants watched the videos: how many people were standing in lines in video A for Feature 4 (Standing in a Line), how many people blocked the robot's path in video B for Feature 2 (Pedestrian Avoidance), and how many people were in the elevator in video B for Feature 3 (Riding an Elevator). We marked a response as invalid and did not use it for our analysis if a participant incorrectly answered any of these questions. Participants with valid responses were compensated 1$ for their participation.

C. Questionnaire about Social Acceptance of Robot

We asked participants to rate the overall social acceptance in terms of uncomfortable, obstructed, and unsafe feelings toward the robot (Fig. 3–1) by using 7-point Likert items (rating from 1: strongly disagree to 7: strongly agree). We asked participants to rate how they accepted the robot after watching each video. We also asked participants to answer whether they are comfortable with the robot's camera

[2]https://crowdworks.co.jp/en/
[3]https://wotipati.github.io/projects/AI-Suitcase-Acceptance/index.html

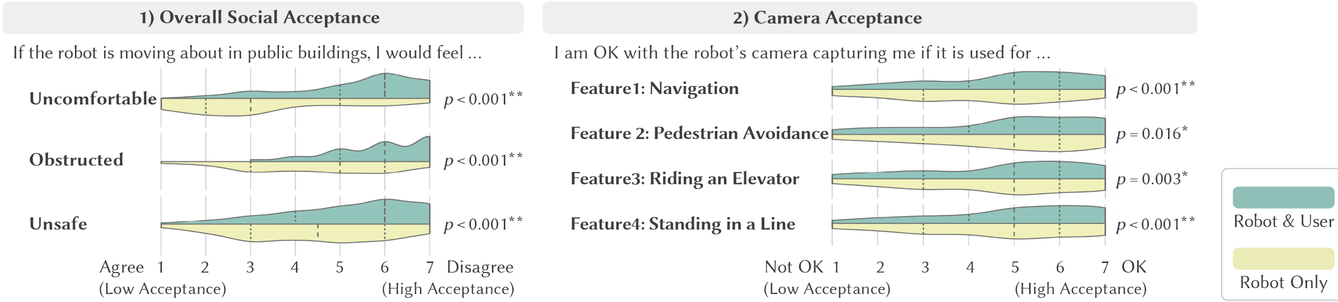

Fig. 3. 1) Overall social acceptance and 2) camera acceptance for cases in which the robot is guiding a user (Robot & User) and moving about alone (Robot Only). * and ** indicate the significance found at the levels of 0.05 and 0.001, respectively.

Condition	For Accessibility Uses?	Data Not Saved?	Not OK (1~3)	OK (5~7)
C1	○ Used for assisting blind people only	○ One-time recognition only	19%	**75.3%**
C2		✕ Saving the data	24.7%	66%
C3	✕ Including other purposes	○	32%	54.7%
C4		✕	**46%**	38%

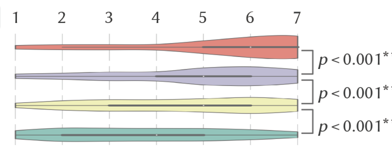

Fig. 4. Overall camera acceptance for each condition. ** indicates the significance found at the levels of 0.001.

capturing them in each of four conditions (C1–C4) using 7-point Likert items. As shown in Fig. 4, these conditions are characterized by whether the captured data are used for only PVI's assistance or not (including other purposes) and whether the captured data are saved or not (one-time detection only).

D. Results

We summarize the results in this section. The list of all questions and the summary of the answers are shown on our web page[3].

While we got 315 responses, 15 participants incorrectly answered our secret questions and were excluded from our analysis. As a result, we acquired answers from 300 individuals (Male: 155, Female: 142, and Decline to State: 3). Participants ranged from 18 to 67 in age (Mean = 37.94 and SD = 9.58); only adults, age 18 or older, were allowed to participate in our online survey.

As the experience interacting with BLV people, 63 participants had personal, volunteer, or work experience interacting with PVI, and 53 had helped strangers who are visually impaired in public spaces. As the experience related to robots, only one participant had been involved in the development, promotion, marketing, or sale of robots, 123 participants had seen robots moving about in public spaces.

1) Robot Only vs. Robot and User: Fig. 3–1 shows the questionnaire results regarding the overall social acceptance toward the robot guiding a user or moving about alone. Our statistical analysis (Wilcoxon signed-rank test with 5% levels of significance) revealed that, for all the questions, the robot guiding a user received significantly higher social acceptance than the robot moving about alone.

Fig. 3–2 shows the questionnaire results regarding the acceptance of the camera for each feature (Feature 1–4). Our statistical analysis (Wilcoxon signed-rank test with 5% levels of significance) revealed that the robot guiding a user received significantly higher camera acceptance for all features than the case of the robot moving about alone.

2) Camera Acceptance: Fig. 4 shows the results of the camera acceptance of the robot guiding a user when we compared the acceptance in four conditions (C1–C4), by using a Wilcoxon signed-rank test with 0.1% levels of significance. The highest acceptance was for C1 (using the captured data for assisting PVI and one-time detection only), followed in order by C2, C3, and C4. In C1, 75.3% of participants answered that they were comfortable with the robot's camera capturing them (5–7 points). However, 19% of participants answered that they did not want to be captured by the robot's camera.

V. Interview with Facility Managers

To explore the concerns that may arise when introducing robots to public buildings, we conducted semi-structured interviews with 15 facility managers in 6 organizations (F1: Shopping Mall, F2: Rehabilitation Center, F3: Polyclinic, F4: Real Estate Development Co., F5: Science Museum, and F6: Discount Store).

A. Procedure

All interviews were conducted over videoconferencing. Interviews began by asking participants how they assist PVI who visit their facilities: *"Do you have a manual or guidelines for visitors with visual impairments?"* Participants then watched video A (Sec. IV-A), which showed the robot guiding a user and presented the robot's four features. After watching the video, we asked participants questions about the concerns that may arise when introducing the robot to their facilities: *"Do you have any safety concerns about the robot moving about in your facilities?"*; *"What criteria and processes must be needed so that your organization considers the robot to present no safety problems?"*; *"Do you have any privacy concerns about the robot's camera?"*; and *"Do* *you have any suggestions for improving the robot?"* The interviews lasted approximately 60 minutes each.

B. Findings

We summarize the prominent comments in this section. The list of other comments is shown on our web page[3].

1) Privacy Concerns: All the organizations answered that they would be fine with the robot's sensors capturing the surrounding information if the captured data are used for assisting PVI: **A1:** *"If the robot is used for assisting PVI and does not record surrounding information, we would like to ask stores in our shopping malls to accept the robot the same as guide dogs. I think it would be essential to inform the stores of the robot's purpose and the handling of the captured data in advance."* (F1). However, all organizations except for F6 were concerned that the public might get suspicious of the cameras attached to the suitcase. They suggested announcing the use of the cameras and handling of the data to visitors of the facility: **A2:** *Because service robots are still uncommon, and some visitors may be suspicious of the robot's camera, it would be good to announce that the robot belongs to the facility. For example, we can put stickers on robots and stores, broadcasts inside the building, and use digital signage."* (F1); and **A3:** *"We should inform visitors that an assistive robot is moving throughout the museum and how captured data is handled by putting a poster at the entrance. Because we agree that PVI do not want to attract people's attention, the robot itself may not have to be overly conspicuous."* (F5).

2) Safety Concerns and Visibility Concerns: F1, F3, and F5 commented that the appearance and movements of the suitcase-shaped robot were so natural and intelligent that the user would not seem visually impaired: **A4:** *"I was surprised that the robot was in the shape of a suitcase. The robot's movements were so intelligent that surrounding people might not notice that the user was visually impaired."* (F3). However, four organizations (F1 and F3–F5) commented that, for safety reasons, the robot and user should inform people that the user is visually impaired: **A5:** *"If surrounding people notice users of guide dogs, they will move out of the way. This robot may be perceived as a suitcase for travel. I think that public would not notice that the user is visually impaired or would not avoid them."* (F1); and **A6:** *"I think that the robot will assimilate into surrounding environments and that people will not avoid it. Because the crowdedness of the facility changes depending on the season, I'm worried about whether the robot can avoid collision in crowded situations. If the robot informs the surrounding people that the user is visually impaired, people could avoid them, reducing the risk of collision."* (F4). In this paper, we defined these concerns about whether PVI should notify their presence to surrounding people as a **"visibility concern"**, and we discussed it with blind people in a focus group session (Sec. VI).

Considering the safety concerns that emerge when introducing autonomous robots to public facilities, the need for criteria that can be used to verify the safety of robots was mentioned by participants: **A7:** *"Because our facility does not have any past cases of safety verification, the introduction of robots will face barriers in terms of safety at this stage. If the public guidelines issued by the government, standards, and safety tests could be used for objective evaluation, I think they could be criteria for introducing robots."* (F4); and **A8:** *"As for guidelines regarding the safety of robots, our stores are unusual environments (corridors are very narrow). Even if there are no legal problems, we do not know if our stores would not have any problems, so I think we need to verify this in our stores."* (F6).

TABLE I
DEMOGRAPHIC DESCRIPTIONS OF FOCUS GROUP PARTICIPANTS.

ID	Age	Gender	Eyesight	Primary Aid
P1	26	Male	Blind since age 10	White cane
P2	33	Female	Blind since age 14	White cane
P3	23	Male	Blind since age 4	White cane
P4	38	Male	Blind since age 30	White cane
P5	56	Male	Blind since birth	White cane
P6	43	Female	Blind since age 3	White cane
P7	64	Male	Blind since age 42	White cane
P8	31	Male	Blind since age 26	Guide dog
P9	29	Male	Blind since age 5	White cane
P10	61	Female	Blind since age 45	White cane
P11	25	Male	Blind since age 15	White cane
P12	52	Male	Blind since age 8	White cane

VI. FOCUS GROUP WITH LEGALLY BLIND PEOPLE

In this study, we asked 12 legally blind participants to use our robot in an office building and then discussed how to widely adopt autonomous navigation robots in the real-world.

We recruited 12 participants (Table I) and conducted three sessions with four participants in each session. We used an e-newsletter for PVI and recruited participants who are legally blind and satisfied the following conditions: 1) consider themselves to have good orientation and mobility skills, 2) often travel independently using their cane or guide dog, and 3) familiar with using smartphones.

A. Procedure

1) Trial Session of Our Robot: After obtaining (IRB-approved) informed consent from participants, we gave an overview of the study and described the robot's interface. We especially explained how to place the left hand on the handle of the robot, how to change the robot's speed, and the vibration signals provided from the suitcase handle. In the trial session, we first asked participants to walk along the route (approximately 160 m) on the first floor. The route included points where 1) the robot conveyed information on POIs (*e.g., "There is a convenience store on the left side."*); 2) an experimenter crossed the participants' route, and the robot stopped to avoid a collision; 3) an experimenter blocked the route and the robot avoided them by moving through free space; and 4) the robot navigated the user to the end of the line, and they followed the line movement.

On the first floor, people constantly walked in or out of the office, restroom, coffee shop, convenience store, etc. While participants were walking with the robot, a researcher was walking behind them to explain the features of the robot and guarantee their safety as well as other pedestrians' safety. After reaching the goal position on the first floor, participants moved from one floor to another by riding an elevator with the robot. We show maps of the office building on our web page[3]. The trial session took around 30 minutes per participant. We conducted the session using two robots and finished all trial sessions with four participants in 60 minutes.

2) Focus Group Session: After completing all routes, we convened a focus group session with participants. The session was semi-structured and focused on the safety, privacy, and visibility concerns pointed out in our online survey and interviews. We also asked the participants the scenarios under which they would use our robot. The focus group session took approximately 90 min, while the whole study took approximately 2.5 h. The blind participants were compensated 90 US dollars each for their time.

B. Findings

We summarize the prominent comments in this section. The list of other comments is shown on our web page[3].

1) Visibility Concerns: All the participants appreciated that the robot's design looked natural and cool. When we asked them about the visibility concerns pointed out by the facility managers (i.e., PVI should inform others that they are visually impaired for safety), five participants (P1–P3, P6, and P10) commented that they would not want to emphasize that they are visually impaired: **A9:** *"It is great that the robot looks stylish. I thought the robot would look more like a navigation machine, but it looks like a natural-looking suitcase and cool. I prefer looking natural and not to be recognized as visually impaired. If the robot looked unsophisticated or conspicuous, I would not want to use it, but I love that this robot is natural. "* (P1); and **A10:** *"I do not use a white cane as a symbol of visual impairment. I use it as a necessary aid for walking. If I can feel safe with the suitcase, I would trust it and walk without the cane."* (P3).

Seven participants (P4, P5, P7–P9, P11, and P12) agreed with the visibility concerns and suggested showing that users are visually impaired. P1, P2, and P11 also commented that when they bump into someone, showing their white cane can reduce the possibility of being in trouble: **A11:** *"I usually walk with a white cane. I'm using a white cane for a walking aid and making people aware I am visually impaired. I think that the suitcase-shaped robot looks cool, but I'm a little worried about the surrounding people not noticing me. I want to show that I have a visual impairment in some way."* (P4); **A12:** *"While I understand that some PVI don't want to emphasize that they are visually impaired, I also realize the advantage of it. For example, when I am walking with my guide dog, surrounding people sometimes ask me, 'do you want some assistance?' "* (P8); and **A13:** *"When I get into an accident such as a collision with someone, if they are aware that I am visually impaired, it can reduce the possibility of me being in trouble."* (P11).

2) Safety Concerns: Participants shared various impressions regarding their safety concerns with the robot. Six participants (P1, P2, P6, P7, P9, and P10) commented that they would not use a white cane while walking with the robot to keep another hand free: **A14:** *"I think there is less risk of collision in a place like today's place (office environment). However, I wondered how the robot would behave in crowded situations such as stations during rush hours."* (P12); and **A15:** *"If I were also using the white cane, I would have concerns that both hands are busy. So, I would not use a white cane while walking with the robot."* (P2).

3) Privacy Concerns: Our study revealed that, while some facility managers were concerned that bystanders might misunderstand the purpose of the robot's camera, which could cause trouble, bystanders would tend to accept the robot's camera if it were used for assisting PVI only and the captured data were not saved at all. When we described these results regarding privacy concerns, while six participants (P1 and P2, P6, and P9–P11) did not mind surrounding people being captured with the camera on the suitcase, the other participants (P3–P5, P7, P8, and P12) were concerned that they might get into trouble if people misunderstood the usage of the camera: **A16:** *"Surveillance cameras are widely used and accepted because the usages of these cameras are understood by society. Similarly, the suitcase's camera will be accepted if surrounding people understand that the camera is used for assisting PVI."* (P7); and **A17:** *"If surrounding people will be concerned about privacy and so on, I think it might be better to clarify the usage of the camera on the suitcase."* (P5).

VII. Discussion

A. Social Acceptance of Suitcase-shaped Navigation Robot

In this study, we observed that social acceptance would be higher for navigation robots assisting blind people than for robots operating. The robot guiding a user received significantly higher social acceptance than the robot moving about alone, as indicated in all the questions (Sec. IV-D.1). One of the major concerns, in general, is the use of cameras, but acceptance was higher if the captured data is to be used for assisting PVI for one-time detection without storing the data (Sec. IV-D.2). This effect is similar to the AT-effects of head mount display usage [3], i.e., people tend to accept technology if it is used for assistive purposes. This finding is unique since autonomous robots usually move around alone, and there are fewer use cases of them being accompanied by a human. Our findings suggest that this characteristic will lower the barrier to deploying robots in public buildings. While we have yet to further investigate this, these findings may suggest that other uses of robots accompanying people with disabilities may have similar advantages, such as autonomic wheelchairs. The results suggest that providing navigation to people with disabilities can help deploy service robots in public buildings in the near future.

B. Visibility Concerns

The robot was designed to appear as a standard suitcase to make the robot to assimilate into the environment in public buildings. The design principle was successfully adapted, and facility managers commented that the use cases were not distinguishable from those in which a person is walking with a standard suitcase. Throughout the study, we received divergent opinions on this aspect.

All the blind participants rated the design highly or expressed that they were comfortable because the robot was able to assimilate into the surroundings (A9 and A10). However, facility managers from four out of six organizations expressed concerns with such assimilation. They thought that it should be clear to others that a person is visually impaired so that PVI are safer. The managers thought that sighted visitors can proactively avoid a collision if they notice a PVI approaching them (Sec. V-B.2).

Five out of 12 blind participants maintained their preference toward the seamless-look in public buildings even after understanding the existence of the visibility concerns (A9 and A10). One notable comment was, *"I prefer to look natural and not be recognized as visually impaired"* (A9). On the other hand, seven blind participants suggested showing that users are visually impaired (A11 and A12). Three participants agreed that there are situations in which they need to make their blindness visible, such as in a crowded environment (A13). Facility managers also suggested solutions such as putting a signboard on top of robots, publicly announcing the existence of navigation robots, or displaying posters to explain the purpose and features of the robots (A5 and A6).

Faucett et al. also reported similar conflicts. They described that externally imposed disability identities may stigmatize those with disabilities as being incapable, or even stereotypically unkempt, and unfashionable. In contrast, they also mentioned that the visibility of the assistive technology, white cane as an example, affords credibility, allowing the user to communicate their needs without words [28].

As for legislation topic [29], in some countries such as Japan, Germany, and Austria, traffic regulations presume that PVI carry a white cane or walk with a guide dog to be "visible" to use public roads. In other countries such as the US and UK, there are no rules requiring PVI to have mobility aids that make them visible, but drivers are asked to yield to PVI using mobility aids. When navigation robots for PVI are ready for use in public places, amendments to regulations may be required in some countries.

The challenge regarding the visibility concern can be one of the essential challenges we face regarding broader deployment. Visibility may have the effect of educating the public about the necessity for such technologies, and consequently, increasing social acceptance. Visibility is mandated in some countries as a part of traffic safety. In addition, PVI tend to feel comfortable blending with everyone else in public buildings. We realized that we need studies to seek a balance between visibility and assimilation along with broadening the usage of such technologies and then propose amendments to regulations to provide for the use of the latest technologies.

C. Privacy Concerns

We investigated privacy concerns based on previous research [3], [4], [5], [6], [7]. An RGB-D camera was attached on top of the robot, and we expected that the feature might invoke privacy concerns. We found that even the public relatively accepts the usage of a camera device for accessibility purposes (Sec. IV-D.2); 75% of people accepted the usage of a camera as long as it was only for PVI and data were not saved. However, only 38% of people accepted the use of a camera if the device were used not only for PVI and data were saved. Facility managers from five out of six organizations expressed concerns about capturing images inside their facilities (A2 and A3). One thing that they were in unanimous agreement about was that visitors might accept the camera if the purpose of assisting PVI were evident and intuitive. Thus, the idea of increasing visibility, as discussed in the previous section, is one solution to this privacy concern. Six blind participants expressed concern that there could be misunderstandings regarding the non-consent nature of using the camera (A17). They agreed to make the purpose of the robot visible.

Privacy concerns are usually considered to be the most serious challenge to practical deployment. We found that it may not be a deal-breaker for social acceptance and practical deployment among stakeholders if it is understood that the purpose is to assist PVI. We still need to explore ways of balancing visibility and comfort for users, but at least, the problem space we need to solve can be narrowed down to the methods and levels of visibility.

D. Safety Concerns

Safety is one obvious concern for practical deployment. As for the subjective sense of safety for PVI, six participants reported that they felt safe and would not use a white cane (A14 and A15). In contrast, the absence of objective safety measures for such navigational robots made facility managers uncomfortable (A7 and A8).

There is one set of standards for services robots, ISO 13482 [30], that define three types of robots: 1) mobile servant robots, 2) physical assistant robots, and 3) person carrier robots. There is no definition for autonomous navigation robot for PVI in the standards, but it could be categorized as a physical assistant robot. Complying with such standards could be a promising way of lowering the barrier to implementation for facility managers and also increasing safety for users.

E. Limitations

This study was conducted in Japan. Social acceptance may vary by country; we hope researchers in other countries conduct comparative studies. Such comparison may reveal new ways of approaching the public to improve acceptance.

This study is based on data collected in a short period, about two months, and this data can be considered a first impression data of this technology. It is expected that social acceptance, especially visibility concerns, may change over time following the exposure to use cases or related information like global trends. We believe that a longitudinal study should be conducted to understand the long-term social acceptance trends among all stakeholders.

In the online survey and the interview sessions with facility managers, the participants did not see the real robot moving in the public with the user in person. It was difficult to show the real robot in person due to the COVID-19 pandemic situation. We designed videos to be understandable and also tried to cover major scenarios. However, demonstrating a real robot with PVI at facilities where sighted visitors walk around may make it easier for all related people to experience practical deployment. We will keep interviewing facility managers to expand pilots and deployments.

VIII. Conclusion

We investigated the acceptance and concerns regarding autonomous navigation robots that guides PVI in public buildings by conducting three studies: an online survey of bystanders, interviews with facility managers, and a focus group interview with blind participants. We found from online survey participants that acceptance was higher when the navigation robot accompanied a blind person than when the robot moved about alone. However, facility managers expressed concern that their customers might misunderstand the purpose of the robot's camera, which could cause trouble because it would not be clear that the camera was being used to aid those with visual impairments. We then discussed privacy and visibility concerns with blind participants. They appreciated that the robot had the potential to assimilate into the surroundings, and five of them commented that they prefer not to be recognized as visually impaired. We then discussed how we could fill the gap between facility managers and visually impaired users. One possible solution is increasing the awareness by putting a sticker on the robot and/or putting up posters in buildings. Further investigation is needed to seek a balance between visibility and blending while broadening the usage of such robots.

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