Discovering User Needs and Preferences for Guide Robots: Challenges and Preliminary Insights

Abena Boadi-Agyemang*, Katherine Shih*, and Aaron Steinfeld

(a) (b)

Fig. 1: Examples of the user study experience. In 1a, the participant studies a tactile map prior to the robot trial. In 1b, the participant navigates with the robot.

I. Introduction

For people who are blind or have low vision (BLV), navigating through complex, unfamiliar crowded spaces can be particularly daunting. Mobility challenges include avoiding static and dynamic obstacles, detecting changes in ground level, finding exits, and adapting to abrupt changes in environment [1]. A number of guide robots have been designed to assist BLV people with navigation tasks in both indoor and outdoor environments [2]–[6]. Much of this research has focused on the technical challenges and contributions of autonomous guide robot systems or acceptance of specific systems.

In this work, we focus on the problem of understanding ideal features of these guide robots, particularly users' sense of orientation, and feelings of comfort and safety. We discuss ongoing research in understanding how BLV users interact with and react to guide robots. Based on preliminary results from a wizard-of-Oz study followed by a semi-structured interview and participatory design phase, we discuss challenges in eliciting user needs and suggest future work.

II. Related Work

A. User Preferences for Navigational Aids

Prior work in discovering user requirements for navigational aids, including guide robots, includes participatory design studies [7]; surveys, interviews, and/or focus groups [8]–[12]; and evaluations of specific systems or algorithms [13]–[17]. Research without a focus on technology, i.e. that aimed at evaluating the everyday experience of BLV people, is also valuable for guide robot design; this includes studies that focus on navigational hazards [18]–[21] and/or orientation and mobility techniques [22], [23].

Common themes arise in the literature. The first key consideration involves attitudes of BLV people towards navigation and mobility that may not be intuitive for sighted designers, highlighting the necessity of participatory design in the development of guide robots. For instance, BLV people rely on landmarks and other cues for navigation, which sighted guides may instinctively avoid [24]. Incorrect assumptions about the physical abilities of BLV people can lead designers to unnecessarily limit options, such as assuming elevators are preferred over stairs [7], [25]. Secondly, the social acceptability of navigation aids play a large part in their acceptance by users. Tolerance of device errors in [11] was mediated by social factors such as the presence of strangers or the social environment. Many users prefer small, unobtrusive devices so as not to stand out [8]. Finally, individual characteristics of users, such as their usual mobility aid, affect their preferences for navigation technologies [13], [26].

In [7], researchers used participatory design to identify interaction modes for building service robots, including guide, escort, and information kiosk modes. In [27], a scenario-based approach was used to determine the design requirements of a mapless robotic navigation system to support blind people with navigating unfamiliar indoor environments. Similar to this work, we incorporate wizard-of-oz methodology to enable users to gain experience with an early prototype. We then use a scenario and dialogue-simulated design approach to identify and evaluate features for future guide robot designs.

B. Perceived Safety and Affect Detection

Positive perception of safety is an important metric for whether robots can be accepted as partners or co-workers and impacts belief in whether users will adopt the agent [28]. Emotion detection by robots can enable the robot to tailor its behavior, crafting an experience that increases a user's perception of safety. A recent extensive review by Rubagotti et al. focused on surveying aspects and themes of and related to perceived safety of autonomous robotic systems [29]. They found that common terms used in physical HRI (pHRI) research that have been related to the notion of perceived safety include trust, comfort, stress or strain, fear, anxiety, and surprise. Within HRI, perceived safety has been measured indirectly using questionnaires [30]–[32], physiological sensing approaches [30]–[34], direct input devices [35], and behavioral measures. However, since current affect detection approaches have largely focused on sighted people, work still needs to be done to identify the modalities that would enable researchers to effectively estimate BLV user affect towards crafting user experiences that foster trust and user acceptance.

III. Methods

We recruited BLV participants (n = 7) from an email list of contacts who had expressed interest in participating in research studies. Participants ranged in age from 35 to 75; four were totally blind or had some light perception, and three were low vision with varying degrees of visual acuity. Participants used a range of mobility techniques, including smart phone, white cane, guide dog, and vision (for those who were low vision). Three participants self-reported to having participated in at least one separate research study with a guide robot. No participants were students at our institution. Our study protocol was approved by our Institutional Review Board. Our study took 150 minutes and participants were compensated $90.

We use a Pioneer P3-DX robot with an attached suitcase handle and additional structures to support a computer, cameras, and other sensors, shown in 2.

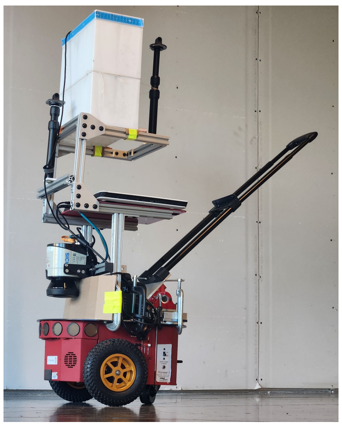

Fig. 2: The prototype guide robot used in the study.

Participants were asked demographic questions about themselves and their level of vision, before completing the Mobility-Related Quality-of-Life Measure for Individuals with Vision Impairments [36]. They were then familiarized with the robot and given the opportunity to touch and ask questions.

In the interaction phase of the study, participants followed the robot through a series of four courses constructed of cardboard obstacles laid out in a large indoor space (approximately 9x19m). The robot was teleoperated along precomputed paths. Course order was counterbalanced between participants. Because the room was large and unfinished, with few cues for orientation, participants were provided with a tactile map of the course to study before each trial. Additionally, a speaker playing a repeated sequence of two notes was placed at the start position to provide an auditory cue. After each course, participants were asked a ten-item subset of the Questionnaire for the Evaluation of Physical Assistive Devices (QUEAD) [37] drawn from the Emotions, Attitude, and Comfort scales. Observation notes were collected throughout, and participants were also asked for any other feedback after each trial.

At the end of the experimental phase, we conducted semi-structured interviews. Participants were asked to reflect on their experiences with the robot as well as to clarify behaviors observed during the trials. Afterwards, we used a modified approach from [38], where a researcher would talk through an imaginary interaction with the guide robot. At each step, participants were asked how they would like the robot to behave and what features or functionality they would include. Finally, we aimed to verify identified system requirements through a dialogue-simulated interaction between the researcher and participant by contextualizing the proposed guide robot interface identified in the previous phase within a specific scenario.

IV. Challenges, Insights, and Future Work:

1) Challenges: Several key challenges in the evaluation of user preferences for this application have arisen in the course of the study, particularly when it comes to evaluating users' perception of safety. First, questionnaire results are not sensitive to users' expressed preferences. Many participants have reported low scores to feelings of anxiety and high scores to feelings of comfort/usability after each trial with the robot. However, both immediately after the trials and when asked follow-up questions during the semi-structured interviews, they also reflect on non-ideal behaviors of the robot such as bringing them too close to obstacles or causing them to maneuver awkwardly. This presents contradictory accounts about how users perceive their safety with the robot.

Furthermore, while we aim to perform post-hoc affect analysis using video footage, the modalities used to estimate affect in BLV are uncertain. For example, while facial expression is common modality used to measure affect, there is evidence that suggests that having visual experiences impacts the production of facial expressions in BLV people, causing variability, intensity, and control in the facial expressions of BLV people [39]. Prior work suggests that biosignals offer promise for navigation-specific tasks [1]. Prosody is also a potential modality for estimating affect [40] that may be useful for our application [41]

2) Insights: Preliminary results support prior work from the literature and introduce additional considerations for design. As in [7], [13], users express a desire for the robot to alert them about obstacles and landmarks, but in line with [26] prefer the degree of information to be customizable. In keeping with prior work about social acceptability, many users prefer to pair their headphones with the robot rather than have it speak aloud. Users prefer the robot to navigate to an exact destination, such as an empty chair in a waiting room or a ticket counter. Finally, based on feedback about robot motions that require awkward maneuvers by the user, robot path planning that explicitly accounts for the user's path is key to comfort.

3) Future Work: This study is ongoing at the time of submission. We plan to continue running participants, and conduct statistical analysis and qualitative coding on the results. We also plan to perform post-hoc analysis on participant video data in conjunction with questionnaire results and qualitative findings, as a step towards identifying insights about the perceived safety of the guide robot system.

REFERENCES

[1] C. Saitis and K. Kalimeri, "Multimodal classification of stressful environments in visually impaired mobility using eeg and peripheral biosignals," *IEEE Transactions on Affective Computing*, vol. 12, no. 1, pp. 203–214, 2018.

[2] T.-K. Chuang, N.-C. Lin, J.-S. Chen, C.-H. Hung, Y.-W. Huang, C. Teng, H. Huang, L.-F. Yu, L. Giarré, and H.-C. Wang, "Deep trail-following robotic guide dog in pedestrian environments for people who are blind and visually impaired - learning from virtual and real worlds," in *2018 IEEE International Conference on Robotics and Automation (ICRA)*, 2018, pp. 5849–5855.

[3] J. Guerreiro, D. Sato, S. Asakawa, H. Dong, K. M. Kitani, and C. Asakawa, "Cabot: Designing and evaluating an autonomous navigation robot for blind people," in *The 21st International ACM SIGACCESS Conference on Computers and Accessibility*, ser. ASSETS '19. New York, NY, USA: Association for Computing Machinery, 2019, p. 68–82.

[4] K. A. Hamed, V. R. Kamidi, W.-L. Ma, A. Leonessa, and A. D. Ames, "Hierarchical and safe motion control for cooperative locomotion of robotic guide dogs and humans: A hybrid systems approach," *IEEE Robotics and Automation Letters*, vol. 5, no. 1, pp. 56–63, 2020.

[5] L. Wang, J. Zhao, and L. Zhang, "Navdog: Robotic navigation guide dog via model predictive control and human-robot modeling," in *Proceedings of the 36th Annual ACM Symposium on Applied Computing*, ser. SAC '21. New York, NY, USA: Association for Computing Machinery, 2021, p. 815–818.

[6] Y. Wei, X. Kou, and M. C. Lee, "A new vision and navigation research for a guide-dog robot system in urban system," in *2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, 2014, pp. 1290–1295.

[7] S. Azenkot, C. Feng, and M. Cakmak, "Enabling building service robots to guide blind people a participatory design approach," in *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 2016, pp. 3–10.

[8] M. A. Hersh and M. A. Johnson, "A robotic guide for blind people. part 1. a multi-national survey of the attitudes, requirements and preferences of potential end-users," *Applied Bionics and Biomechanics*, vol. 7, no. 4, pp. 277–288, 2010. [Online]. Available: https://doi.org/10.1080/11762322.2010.523626

[9] ——, "A robotic guide for blind people part 2: Gender and national analysis of a multi-national survey and the application of the survey results and the cat model to framing robot design specifications," *Appl. Bionics Biomechanics*, vol. 9, no. 1, p. 29–43, jan 2012.

[10] M. A. Williams, A. Hurst, and S. K. Kane, ""pray before you step out": Describing personal and situational blind navigation behaviors," in *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*, ser. ASSETS '13. New York, NY, USA: Association for Computing Machinery, 2013. [Online]. Available: https://doi.org/10.1145/2513383.2513449

[11] A. Abdolrahmani, W. Easley, M. Williams, S. Branham, and A. Hurst, "Embracing errors: Examining how context of use impacts blind individuals' acceptance of navigation aid errors," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ser. CHI '17. New York, NY, USA: Association for Computing Machinery, 2017, p. 4158–4169. [Online]. Available: https://doi.org/10.1145/3025453.3025528

[12] M. Bonani, R. Oliveira, F. Correia, A. Rodrigues, T. Guerreiro, and A. Paiva, "What my eyes can't see, a robot can show me: Exploring the collaboration between blind people and robots," in *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility*, ser. ASSETS '18. New York, NY, USA: Association for Computing Machinery, 2018, p. 15–27. [Online]. Available: https://doi.org/10.1145/3234695.3239330

[13] S. Kayukawa, T. Ishihara, H. Takagi, S. Morishima, and C. Asakawa, "Guiding blind pedestrians in public spaces by understanding walking behavior of nearby pedestrians," *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 4, no. 3, sep 2020. [Online]. Available: https://doi.org/10.1145/3411825

[14] J. a. Guerreiro, E. Ohn-Bar, D. Ahmetovic, K. Kitani, and C. Asakawa, "How context and user behavior affect indoor navigation assistance for blind people," in *Proceedings of the 15th International Web for All Conference*, ser. W4A '18. New York, NY, USA: Association for Computing Machinery, 2018. [Online]. Available: https://doi.org/10.1145/3192714.3192829

[15] A. D. P. dos Santos, F. O. Medola, M. J. Cinelli, A. R. Garcia Ramirez, and F. E. Sandnes, "Are electronic white canes better than traditional canes? a comparative study with blind and blindfolded participants," *Univers. Access Inf. Soc.*, vol. 20, no. 1, p. 93–103, mar 2021. [Online]. Available: https://doi.org/10.1007/s10209-020-00712-z

[16] N. Fallah, I. Apostolopoulos, K. Bekris, and E. Folmer, "The user as a sensor: Navigating users with visual impairments in indoor spaces using tactile landmarks," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '12. New York, NY, USA: Association for Computing Machinery, 2012, p. 425–432. [Online]. Available: https://doi.org/10.1145/2207676.2207735

[17] E. E. Pissaloux, R. Velázquez, and F. Maingreaud, "A new framework for cognitive mobility of visually impaired users in using tactile device," *IEEE Transactions on Human-Machine Systems*, vol. 47, no. 6, pp. 1040–1051, 2017.

[18] W. Jeamwatthanachai, M. Wald, and G. Wills, "Indoor navigation by blind people: Behaviors and challenges in unfamiliar spaces and buildings," *British Journal of Visual Impairment*, vol. 37, no. 2, pp. 140–153, 2019. [Online]. Available: https://doi.org/10.1177/0264619619833723

[19] R. Manduchi and S. Kurniawan, "Mobility-related accidents experienced by people with visual impairment," *Insight: Research and Practice in Visual Impairment and Blindness*, vol. 4, 01 2011.

[20] R. M. Kitchin, R. D. Jacobson, R. G. Golledge, and M. Blades, "Belfast without sight: Exploring geographies of blindness," *Irish Geography*, vol. 31, no. 1, pp. 34–46, 1998. [Online]. Available: https://doi.org/10.1080/00750779809478630

[21] Y. Zhao, E. Kupferstein, D. Tal, and S. Azenkot, ""it looks beautiful but scary": How low vision people navigate stairs and other surface level changes," in *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility*, ser. ASSETS '18. New York, NY, USA: Association for Computing Machinery, 2018, p. 307–320. [Online]. Available: https://doi.org/10.1145/3234695.3236359

[22] M. Hersh, "Route learning by blind and partially sighted people," *Journal of Blindness Innovation and Research*, vol. 10, no. 2, 2020.

[23] K. Müller, C. Engel, C. Loitsch, R. Stiefelhagen, and G. Weber, "Traveling more independently: A study on the diverse needs and challenges of people with visual or mobility impairments in unfamiliar indoor environments," *ACM Trans. Access. Comput.*, vol. 15, no. 2, may 2022. [Online]. Available: https://doi.org/10.1145/3514255

[24] M. A. Williams, C. Galbraith, S. K. Kane, and A. Hurst, "Just let the cane hit it: How the blind and sighted see navigation differently," in *Proceedings of the 16th International ACM SIGACCESS Conference on Computers &; Accessibility*, ser. ASSETS '14. New York, NY, USA: Association for Computing Machinery, 2014, p. 217–224. [Online]. Available: https://doi.org/10.1145/2661334.2661380

[25] J. a. Guerreiro, D. Ahmetovic, D. Sato, K. Kitani, and C. Asakawa, "Airport accessibility and navigation assistance for people with visual impairments," in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ser. CHI '19. New York, NY, USA: Association for Computing Machinery, 2019, p. 1–14. [Online]. Available: https://doi.org/10.1145/3290605.3300246

[26] D. Ahmetovic, J. a. Guerreiro, E. Ohn-Bar, K. M. Kitani, and C. Asakawa, "Impact of expertise on interaction preferences for navigation assistance of visually impaired individuals," in *Proceedings of the 16th International Web for All Conference*, ser. W4A '19. New York, NY, USA: Association for Computing Machinery, 2019. [Online]. Available: https://doi.org/10.1145/3315002.3317561

[27] M. Kuribayashi, T. Ishihara, D. Sato, J. Vongkulbhisal, K. Ram, S. Kayukawa, H. Takagi, S. Morishima, and C. Asakawa, "Pathfinder: Designing a map-less navigation system for blind people in unfamiliar buildings," in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, ser. CHI '23. New York, NY, USA: Association for Computing Machinery, 2023. [Online]. Available: https://doi.org/10.1145/3544548.3580687

[28] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *International journal of social robotics*, vol. 1, pp. 71–81, 2009.

[29] M. Rubagotti, I. Tusseyeva, S. Baltabayeva, D. Summers, and A. Sandygulova, "Perceived safety in physical human–robot interaction—a survey," *Robotics and Autonomous Systems*, vol. 151, p. 104047, 2022.

[30] S. Nonaka, K. Inoue, T. Arai, and Y. Mae, "Evaluation of human sense of security for coexisting robots using virtual reality. 1st report: evaluation of pick and place motion of humanoid robots," in *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA'04. 2004*, vol. 3. IEEE, 2004, pp. 2770–2775.

[31] D. Kulic and E. Croft, "Anxiety detection during human-robot interaction," in *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 2005, pp. 616–621.

[32] D. Kulić and E. Croft, "Physiological and subjective responses to articulated robot motion," *Robotica*, vol. 25, no. 1, pp. 13–27, 2007.

[33] P. Rani, N. Sarkar, C. A. Smith, and L. D. Kirby, "Anxiety detecting robotic system–towards implicit human-robot collaboration," *Robotica*, vol. 22, no. 1, pp. 85–95, 2004.

[34] D. Kulic and E. A. Croft, "Affective state estimation for human–robot interaction," *IEEE transactions on robotics*, vol. 23, no. 5, pp. 991–1000, 2007.

[35] K. L. Koay, M. L. Walters, and K. Dautenhahn, "Methodological issues using a comfort level device in human-robot interactions," in *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005.* IEEE, 2005, pp. 359–364.

[36] E. M. Lethbridge and M. C. Muldoon, "Development of a mobility-related quality-of-life measure for individuals with vision impairments," *Journal of Visual Impairment & Blindness*, vol. 112, no. 2, pp. 169–181, 2018. [Online]. Available: https://doi.org/10.1177/0145482X1811200205

[37] J. Schmidtler, K. Bengler, F. Dimeas, and A. Campeau-Lecours, "A questionnaire for the evaluation of physical assistive devices (quead): Testing usability and acceptance in physical human-robot interaction," in *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 2017, pp. 876–881.

[38] N. G. Sahib, T. Stockman, A. Tombros, and O. Metatla, "Participatory design with blind users: A scenario-based approach," in *IFIP TC13 International Conference on Human-Computer Interaction*, 2013. [Online]. Available: https://api.semanticscholar.org/CorpusID:18552803

[39] D. Valente, A. Theurel, and E. Gentaz, "The role of visual experience in the production of emotional facial expressions by blind people: A review," *Psychonomic bulletin & review*, vol. 25, no. 2, pp. 483–497, 2018.

[40] R. A. Calvo and S. D'Mello, "Affect detection: An interdisciplinary review of models, methods, and their applications," *IEEE Transactions on Affective Computing*, vol. 1, no. 1, pp. 18–37, 2010.

[41] A. T. Martins, L. Faísca, H. Vieira, and G. Gonçalves, "Emotional recognition and empathy both in deaf and blind adults," *The Journal of Deaf Studies and Deaf Education*, vol. 24, no. 2, pp. 119–127, 2019.