



Research Report **InsEYEght**

Despite advances like self-driving cars, daily tasks such as grocery shopping remain difficult for the visually impaired. Since they make up a small portion of the population, AI solutions tailored to their needs remain an underdeveloped niche market. Yet, fully harnessing AI's potential could be transformative. Our research addresses this by examining both everyday challenges and the current assistive tools, aiming to bridge the gap between AI's potential and its real-world application for the visually impaired.

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Preface by the Supervisor

Prof. Dr.-Ing. Johannes Betz

The importance of ensuring safety and accessibility in public spaces for blind and visually impaired individuals cannot be overstated. As our cities become more complex and technologically advanced, so must our efforts to include and protect all members of society. The insEYEght team of #class2024 focuses mainly on this challenge. It has the potential to raise awareness, identify real-world needs, and drive meaningful innovation in areas that often receive too little attention.

What makes the endeavor of the team insEYEght particularly valuable is its interdisciplinary foundation. When expertise from different fields – engineering, medicine, informatics, and beyond – comes together, it creates a fertile ground for creative, holistic solutions.

This blending of perspectives is a strength and a necessity when addressing complex societal issues. It reflects the reality of modern research and innovation, where collaboration across disciplines leads to deeper understanding and more impactful outcomes. The project insEYEght stands out as a highlight for its empathetic and research-driven approach to understanding the needs of blind and visually impaired individuals, combining technical innovation with social responsibility to create real impact.

It is encouraging to see critical societal questions tackled with seriousness, empathy, and scientific rigor. The outcomes of this work will extend far beyond technical solutions; they will contribute to a broader culture of awareness, respect, and inclusion. ■



Supervisor Insights

What is your research interest or motivation for science?

My research centers on autonomous systems, intelligent mobility, and the interaction between humans and machines. What motivates me most is the opportunity to develop technologies that can directly improve lives – whether it's through making traffic safer, cities smarter, or, in this case, public spaces more inclusive. Science gives us tools to solve real problems, and that translation from theory to tangible impact is what keeps me engaged and excited.

What was your best TUMJA moment?

One of my favorite TUMJA moments was witnessing a team's initial concept evolve into a real idea and solution through collaboration and shared passion. That transformation – from idea to impact – never gets old. But above all, it's the genuine curiosity, energy, and commitment of the scholars that impress me every time.

What does mentoring the team mean for your own research?

Mentoring this team is a refreshing and inspiring process. It pushes me to rethink familiar problems through different lenses and constantly challenges my assumptions. The exchange is never one-way – guiding young researchers sharpens my own thinking and creates new research questions.

What experiences do you relate to talent mentoring programs?

Mentoring programs like TUMJA are a unique breeding ground for interdisciplinary collaboration. I've seen firsthand how talented individuals from diverse fields come together and achieve things no single discipline could accomplish alone. My experience has shown that mentoring is not just about knowledge transfer – it's about unlocking potential and nurturing curiosity.

What experience from your studies/career would you like to share with the scholars?

One experience that shaped me deeply was working on my first real-world autonomous vehicle project. It taught me how messy, unpredictable, and rewarding innovation can be. The biggest lesson: Don't be afraid of failure! – Failure is often the best teacher.

How did your work as a supervisor influence you individually?

Supervising students has taught me to be more patient and has pushed me to rethink how I communicate complex ideas. It's made me more aware of how I explain content and how important clarity is when working with people from different backgrounds.

The Journey of insEYEght

Overcoming Invisible Barriers: The Promise of AI for the Visually Impaired

Let's imagine: It's early in the morning. Your alarm rings, but instead of simply checking your phone, you carefully feel around your nightstand until you find your talking clock. Still drowsy, you get up, but even the short walk to the bathroom presents the first challenge: Did you leave everything in its place last night? A misplaced chair can already turn into a dangerous obstacle.

Does this sound unfamiliar to you? If yes, it is probably because, for people with no visual impairment, it is hard to put themselves into this position. The affected, however, face innumerable challenges in every aspect of life that most people do not even consider: Is this a tinned can with pineapples or pickles? On which platform is bus number 74 leaving?

Fully sighted people hardly realize the challenges visually impaired people have to tackle. One thing they do realize instead is the racing technological progress that is reshaping the world around them. This contrast highlights a deeper issue at play: our ability to innovate often outpaces our ability to reflect on how those innovations affect all members of society. Or to put it in the words of Yuval Harari: *"Humans were always far better at inventing tools than using them wisely."*

While some are afraid of the disruptive power of AI, others praise its vast potential. Utilizing the unprecedented potential of AI might include more sophisticated aid tools for blind people. However, other applications like autonomous driving attract the most attention. Indeed, they affect all of us and are therefore more profitable

for economically driven companies. This suggests that applications for visually impaired people are still underdeveloped, even if they are receiving more attention. From an economic point of view, the visually impaired might be considered a niche target group. But from a humanistic perspective, the situation looks very different: as a vulnerable group that relies more heavily on external support, their needs should be prioritized.

We, as humans, must not forget that at some point in our lives, we all depend on the help of others – whether as newborns, in old age, or when facing challenges that limit our independence, such as temporary or permanent impairments. What makes us human? Certainly, phases of vulnerability and dependence at some points in our lives. But also, the urge to overcome these dependencies and the necessary creative power are among the most valuable human assets. And perhaps most profoundly, empathy. The ability to put ourselves into the position of another individual, trying to understand their feelings and needs, changes the way we treat others, shapes our societies, and thus is a crucial part of what makes us human.

This is why the team InsEYEght chose to respond to the call of this year's class by exploring the potentials of the latest technology for visually impaired individuals.

The project was supervised by Johannes Betz, a professor of autonomous driving at TUM. His impressive demonstration of what is already technically feasible shaped the project's core rationale:

“Much of the technical foundations are already there; all it needs for supporting visually impaired people is a context-specific adaptation.” Learning more about the needs of visually impaired people and their struggles with traditional aids could enable the implementation of AI in suited problem areas. In this pursuit, we conducted interviews with affected individuals.

The insights into the everyday life of the affected quickly made clear that “To see, or not to see, is not the question here.” When talking about visual impairments, one must distinguish much more than “sighted and blind.” The range between these two extremes covers multiple different visual disorders, all with unique characteristics and thus with special needs regarding aid tools. For example, people with visual impairment since birth tend to emphasize a signalling function of aid tools; people affected later in their lives prefer aid tools which are less noticeable and leave them “undercover.”

This illustrates that expectations about aid tools are very individual, which makes highly adaptable AI a promising solution. However, the data from the interviews also shows that blind people and their aid tools keep up with the times. For some traditional aid tools, “smart” versions exist, such as blindness canes with ultrasonic obstacle detection. However, many of these functional upgrades have usability downgrades; in the case of smart canes, many users mention the increased weight as a severe limitation. Furthermore, the smartphone paired with certain apps is nowadays the most used aid tool, especially when the focus lies on

information gathering rather than obstacle detection. *“We have found visually impaired people, especially in older age-brackets, to be very technologically experienced and open. While sighted people could perfectly well find their way in the world 30 years ago, visually impaired people always struggled. Hence for sighted people the incentive to deal with new technology is much smaller than for visually impaired people. For the latter, smartphones bear too much potential for people to miss out on, so they make an effort to get into the latest technology,”* summarizes Max, one of the team members. This is fundamental for the pursuit of InsEYEght, as it shows that visually impaired people are already confident with technology and thus smartphones are a promising platform for establishing AI-aided tools. In addition, dedicated hardware, such as glasses or devices with haptic feedback, are also feasible if required.

Another finding from systematically surveying the aid tools already in use is that apps for many applications already exist. Sometimes when participants talked about a particular problem, this would prompt others to report that a solution tailored to this problem already exists. It goes without saying that enhancing the usage of what is already on the market is more straightforward than developing anything new.

The findings of our research contribute to addressing the most pressing wish expressed by participants many times throughout the project: Visually impaired people want to take part in life again. ■

Research Report – insEYEght

Bridging technology and accessibility to empower the visually impaired.

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Abstract

In Germany, approximately 1.2 million people are considered blind or visually impaired (Institut der deutschen Wirtschaft Köln, 2023). Despite the availability of various assistive technologies – such as white canes, guide dogs, screen readers, and smart glasses (Deutscher Blinden- und Sehbehindertenverband e.V., 2025) – navigating daily life remains a significant challenge for many. These tools often lack the ability to provide real-time, context-aware support, particularly in dynamic or unfamiliar environments. This limitation underscores the need for more intuitive and responsive systems, forming the basis for the present study.

The research's primary purpose was to identify the main needs and challenges faced by blind and visually impaired individuals. The focus was set on exploring whether advancements in technology, such as Artificial Intelligence, could be used to enhance the quality of life of the target group. The study was narrowed down to close-range tasks, meaning activities requiring close vision, such as navigating public transport or reading text on signs.

In this study, we conducted interviews both online and in person. The participants were recruited through support groups, where we established initial contact and invited them to take part in the research. The interviews followed a semi-structured format, allowing for both guided questions and open-ended responses to gain deeper insights. The data collected was then transcribed and analyzed qualitatively using MAXQDA, a software tool for qualitative data analysis. This allowed for systematic coding and identification of key themes within the responses.

The collected data indicates that digital aids – particularly smartphone apps – are gaining the most traction due to their ability to integrate naturally into users' routines and address everyday challenges like grocery shopping or boarding the correct bus.

Background

Globally, millions of people live with visual impairments (Vision Loss Expert Group, 2017), including approximately 164,000 blind and 1,066,000 visually impaired individuals in Germany alone (In-

stitut der deutschen Wirtschaft Köln, 2023). These individuals rely on traditional mobility aids such as guide dogs and white canes, which, while effective, have limitations when navigating complex urban environments. Although assistive technologies, such as screen readers and navigation apps, have improved accessibility in certain contexts, there remains a significant gap in leveraging AI-powered wearable devices to enhance independent mobility and safety (Manirajee, L., Shariff, S. Q. H., & Rashid, S. M. M., 2024).

Thanks to rapid technological progress, including advances in the field of artificial intelligence (AI), blind individuals in some parts of the world can now be transported autonomously to their desired destinations. However even the daily journey to the supermarket remains a significant challenge for people with visual impairments (Bastola, A., Wang, H., Haeri Boroujeni, S. P., Brinkley, J., Moshayedi, A. J., & Razi, A., 2024). Despite the rise of AI-driven systems – such as autonomous vehicles, voice assistants, and smart home devices – the specific needs of blind and visually impaired individuals are often overlooked in mainstream technological development (Kacperski, C., Kutzner, F., & Vogel, T., 2023).

For blind individuals, safe and independent mobility remains a fundamental challenge. Crossing streets, avoiding obstacles, and navigating public transportation systems require constant attention and often external assistance. Wearable technologies, including smart glasses, haptic feedback devices, and AI-powered navigation tools, hold great promise for improving accessibility. Recent advancements in computer vision, machine learning, and sensor technologies have enabled real-time object recognition, obstacle detection, and route guidance tailored to the specific needs of visually impaired users. For example, AI-driven navigation systems can assist in identifying street crossings, locating buildings, and detecting moving obstacles, providing crucial feedback through auditory or haptic signals (Baig et al., 2024). A pilot project has also demonstrated the potential of AI-enhanced augmented reality devices – such as modified HoloLens headsets – to help visually impaired individuals recognize their surroundings and identify familiar faces (Brilli et al., 2024).

Nevertheless, challenges remain in optimizing these technologies for daily use. Issues such as accuracy, usability, affordability, and user acceptance must be addressed to ensure widespread adoption. In addition, ethical considerations – particularly concerning privacy in AI-powered visual recognition – must be carefully managed to protect users' rights and autonomy (Feichtenbeiner et al., 2022).

This research focused on identifying the gap that AI-powered aids could fill by examining the main challenges faced by blind and visually impaired individuals, as well as the limitations of current assistive devices. By engaging with experts and incorporating user feedback, we aimed to uncover unmet needs and to explore how AI-driven solutions could promote greater independence in a technology-driven world.

Goals and Methods

In our study, selecting a qualitative approach was fundamental due to the specific objectives we aimed to achieve. While quantitative research, with its characteristic large sample sizes, can deliver generalizable results and enable group comparisons, our study required a more nuanced understanding. The qualitative approach enabled us to grasp the complexity of the needs and challenges faced by blind and visually impaired individuals. It allowed us to incorporate factors such as the personality of participants, their situational contexts, and their direct responses into our analysis (Xiong X. et al., 2022). Our semi-structured interviews, characterized by open-ended questions, provided the necessary flexibility, allowing for the adaptation of inquiry based on participants' responses. This adaptable method could capture insights potentially lost in pre-determined survey questions.

Research Question:

The qualitative approach, which focused on capturing a rich and detailed picture of visually impaired people's experiences, led us to our primary question. We were motivated to investigate: *“What are the most pressing issues and challenges visually impaired and blind people face daily that can be approached by AI assisted tools?”*

Sample

The sample size of 30 interviewees consists of visually impaired individuals across Germany (N=30) with varying degrees of visual impairment. There are 17 males and 13 females. The average age is 55.3, the minimum is 29 and the maximum is 86 (n=20). Five participants live in rural areas and 16 live in middle-sized or larger cities [≥ 20.000 inhabitants] (n=21). Of the 30 visually impaired, 6 are blind, 13 are severely visually impaired / nearly blind and 8 are visually impaired (n=27). Nine participants have had reduced sight since their childhood and 16 subjects lost their sight after the age of 16 (n=25).

Study Structure

1. Preliminary Phase - First Contacts:

The study began with an initial outreach to the regional group of Pro Retina, a self-help organization dedicated to visually impaired individuals. This first contact served to gain an initial sense and understanding of the environment and circumstances in which visually impaired people navigate their daily lives today. The organization supports and advocates for better living conditions and research advancements for those affected. After initiating first contact with the leader of the regional group, we were invited to attend one of Pro Retina's monthly meetings. While no interviews were conducted during this visit, the interaction provided valuable initial insights into the existing challenges faced by individuals in the group. The participants of the meeting shared ideas on future possibilities but also expressed critical points of the existing aids. This was crucial to refining the study's focus and generating new ideas for the interview process. Additionally, we were able to establish important contacts for future interviews.

2. Additional Insights

To further enrich our understanding of the challenges visually impaired face as well as the already existing solutions, we attended the SightCity Fair held in Frankfurt. SightCity is the largest international fair dedicated to innovative aids for the blind and visually impaired. Our visit offered hands-on insights into existing solutions and ongoing research, and facilitated meaningful exchanges with experts, scientists, professors, and individuals directly affected by visual impairment. Participating in the fair proved crucial for improving the interview questions and understanding the broader context of the study. Additionally, it also facilitated the acquisition of valuable new contacts for future interviews.

3. Interview Design and Recruitment

Building on the insights gained from Pro Retina and the SightCity Fair, the interview questionnaire was finalized. To recruit participants, various organizations were contacted, in addition to the network established during the earlier phases of the project. The majority of the participants were obtained through Pro Retina. Other key organizations were the *Deutscher Blinden- und Sehbehindertenverband e.V.*, the *Bayerischer Blinden- und Sehbehindertenbund e.V.*, and the *Allgemeiner Blinden- und Sehbehindertenverband e.V. Berlin*.

In total, over 100 individuals expressed interest in participating in the study and 30 participants were selected yielding converging results, meaning that no new themes or insights emerged in the later stages of data collection. The selected participants were chosen randomly.

4. Conducting the Interviews

The interviews were structured to resemble a conversation rather than a formal survey. This approach allowed interviewees to elaborate on their experiences and offer insights beyond the scope of the prepared questions. Following an exploratory approach, our main objective with the chosen interview style was to create a comfortable and open setting for the interviewees. Depending on the course of the conversation, additional questions might have been asked to explore specific topics in greater depth. This was particularly done when we felt that the interviewee had more to share than initially stated, or when new aspects emerged that, as non-affected individuals, we hadn't considered beforehand. This was precisely the value of conducting interviews, uncovering insights that go beyond our own perspective.

The data collection phase spanned two months and served as the foundation for subsequent analysis.

Materials

Category System

To design our interviews as well as planning the subsequent data analysis, we grounded our approach in Mayring's qualitative content analysis methods (Mayring, P., 2015). This approach provided us with a structured yet flexible framework. This structure ensured that, both data collection and interpretation, which were carried out by different team members, remained consistent, as it left less room for personal interpretation.

Our category system was developed to structure and analyze the interview data systematically. It included deductively derived categories, based on theoretical concepts, as well as inductively developed themes that emerged during the interviews to better reflect the data. The developed category system (see Table 1) was afterwards used for our qualitative content analysis. It provided a structured

way to organize our interview data, which facilitated the interpretation. The themes and patterns of the interviews could easily be identified as various segments of text were assigned to defined categories. This allowed us to make meaningful comparisons between the interviews. In accordance with Mayring, this ensured that the analysis remained focused and analytically grounded.

The following table provides an overview of the final category system:

Main Category	Subcategory	Specific Aspect	Details
Demographic Data	Gender	–	–
	Age	–	–
	Employment Status	Full-time	–
		Part-time	–
	Living Situation	Alone	–
		Accompanied	–
	Place of Residence	Rural	–
		Urban	–
Current Problem Areas	Visual Impairment	Degree of Impairment	Description, visually impaired (low vision) or blind In accordance with WHO (World Health Organization: International Classification of Impairments, Disabilities, and Handicaps 1980; page 79)
		Congenital vs Acquired	–
	Private Space	Obstacles	–
		Information	–
	Public Space (Transportation)	Obstacles	–
		Information	–
	Public Space (Enclosed)	Obstacles	–
Main Transportation	Public Space	Information	–
		Accidents	Obstacles
	Private	Walking	Occurrence Rate, Severity, caused by Others vs Self-inflicted Alone, With Assistance
		Car	–
	Public	Bicycle	Alone, With Assistance
		Local Transportation	Alone, With Assistance, Subdivided (Bus, Train)
		Long-distance Transportation	Alone, With Assistance, Subdivided (Bus, Train, Airplane)
Assistive Devices	Present (currently in use)	Traditional Assistive Devices (e.g. Cane)	Pros & Cons
		Innovative Smart Assistive Devices (e.g. Smart Cane)	Pros & Cons
		Digital Assistive Devices (purely software, e.g. BeMyEyes)	Pros & Cons
	Past (no longer in use)	Past Assistive Devices	Device, Reason for Purchase, Reason for Discontinuation
	Future (Desired of Aids)	Properties & Functionalities & Feedback Mechanism	Feedback (verbal, acoustic, vibration/haptic feedback, customizable [Yes/No])

Table 1: Category system

Recordings & Transcription

Before starting the interviews all the interviewees were asked for permission to record the conversation. Of the 30 interviews conducted, 24 were recorded using either a recording device or Zoom’s built-in feature. The remaining six were documented through detailed notes due to technical limitations. The recordings were transcribed using the latest Whisper speech-to-text model. Whisper was selected for its swift ability to process large volumes of audio data. After the first automated transcription, each transcript was manually reviewed following Kuckartz’s transcription guidelines to ensure correctness and consistency (Kuckartz, 2002). This step was crucial to correct transcription errors of the Whisper model. All recordings and contact information are stored until the project is finished in June 2025.

For the analysis, we began by using MAXQDA to code the interview transcripts. The coding process was guided by our predefined category system (see Table 1). This facilitated the identification of patterns across the interviews. To ensure consistency and reliability in our interpretation, each coded transcript was independently reviewed by a second team member. Any discrepancies were resolved through discussion and mutual consensus. Once the coding process was completed, the coded segments were exported from MAXQDA as an Excel file for further processing. In the next step, a Python script was used to clean the exported data by removing irrelevant elements such as timestamps, and merging fragmented segments. This preprocessing step improved the readability and usability of the data for subsequent synthesis. Afterward, the relevant coded text passages were manually reviewed. Key content was extracted from these passages and organized into a structured Google Sheet for further analysis.

Outcome and Discussion

The study classified assistive tools into three distinct categories: traditional, innovative/smart, and digital aids. Traditional tools comprised devices such as guide dogs, white canes, sunglasses, and handheld magnifiers. In contrast, smart tools encompass advanced devices like the OrCam, ultrasonic devices, bone-conduction headphones, and other interactive gadgets. Digital aids refer specifically to software-based tools – primarily smartphone applications – such as MyWayPro, the DB App, BeMyEyes, screen readers, and magnifier apps, which utilize the multifunctionality and widespread availability of modern smartphones.

Distribution of Aid Usage by Disability Category

As illustrated in Figure 1, the prevalence of aid types differs across disability groups. For individuals who are blind, traditional tools were the most common, followed by smart aids and digital tools. Among visually impaired participants, digital aids dominated usage. A similar trend was observed in the severely visually impaired / nearly blind category, where digital tools were again predominant (over 40%), succeeded by smart aids and traditional tools. Overall, digital tools emerged as the most frequently recorded category with 49 devices, compared to 37 traditional and 36 smart devices. This shift toward digital solutions is largely driven by the ubiquity and cost-effectiveness of smartphones, which all participants owned. Unlike traditional or smart devices that typically require specialized training or entail higher expenses, smartphones offer a versatile platform enriched with numerous assistive applications, making them a highly accessible and empowering option for visual support. The three different aid types will now be examined further.

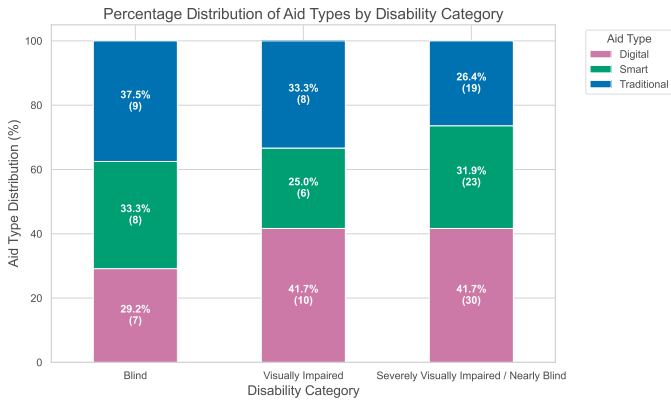


Figure 1: Percentage Distribution of Aid Types by Disability Category

Smart Aid Usage Patterns

Figure 2 compares the usage of smart aids across the three visual disability categories. The tools are grouped into five categories based on their primary functions. Reading tools support reading and magnifying text. Accessibility tools help users enjoy accessible audiovisual content. Communication tools offer real-time support and screen access. Navigation and orientation tools assist with spatial awareness and travel. Visual recognition tools identify surroundings and objects.

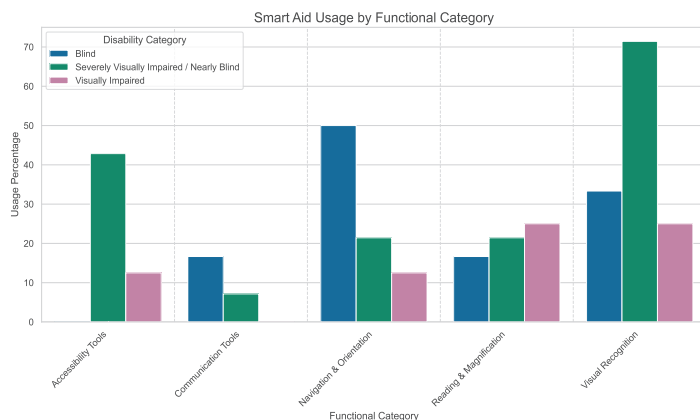


Figure 2: Comparison of Smart Aid Usage

The data reveal varied preferences that align with the severity of impairment. For example, the OrCam is predominantly used by the severely visually impaired / nearly blind group – with adoption rates exceeding 60%. Conversely, devices such as the vibration belt, ultrasonic device, and bone-conduction headphones are chiefly used by individuals who are blind. These findings highlight the necessity of aligning assistive technologies with the specific requirements of distinct user groups.

Digital Aid Usage Patterns

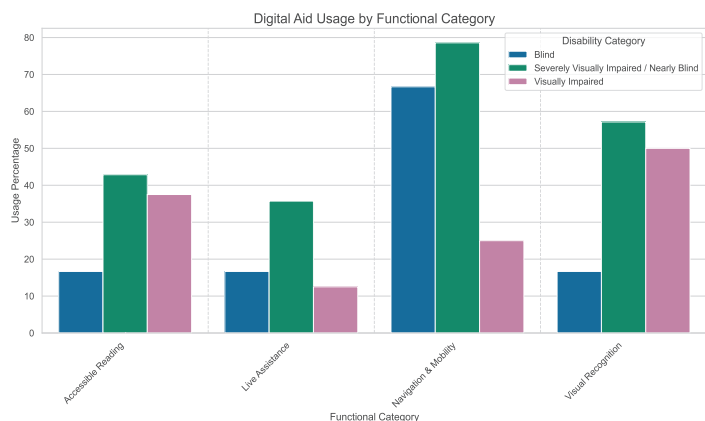


Figure 3: Comparison of Digital Aid Usage

Figure 3 presents an analysis of digital aid usage across disability categories, revealing distinct patterns based on visual impairment severity. The aids were categorized in the same way as the smart tools, except the Reading and Magnifying category, which is no longer included. Applications such as Be My Eyes, Screen Reader, and Google Maps are used consistently among all groups. Notably, these are all digital apps, highlighting the importance of smartphones for visually impaired people. Seeing AI is used most by severely visually impaired people, indicating it is most useful for this user group.

Traditional Aid Usage Patterns

In Figure 4, the usage of traditional aids is compared among blind, visually impaired, and severely visually impaired / nearly blind individuals. The white cane, though a longstanding tool, remains the most widely used traditional mobility aid today – especially among blind individuals (over 80%) and those who are severely visually impaired or nearly blind (around 78%) – underscoring its continued relevance and essential role in independent navigation. While blind participants showed a higher reliance on identification armbands, visually impaired individuals tended to favor sunglasses and magnifying glasses – with sunglasses usage reaching nearly 40%. Other aids, such as edge filter glasses, guide dogs, and standard glasses, were utilized less frequently across all groups, although magnifying glasses saw slightly higher use among the severely visually impaired. This distribution reinforces the enduring importance of traditional aids – especially the white cane – for

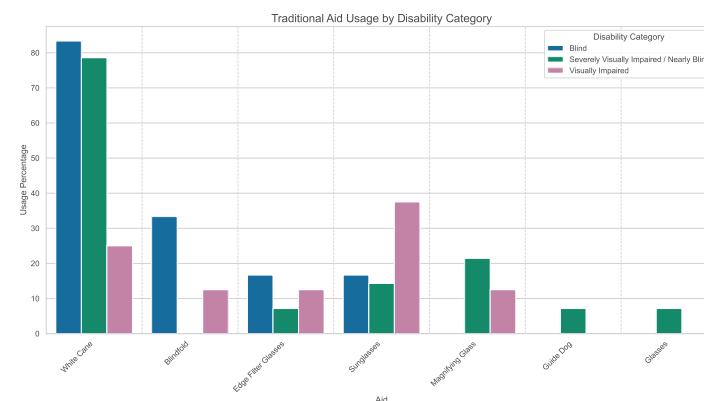


Figure 4: Comparison of Traditional Aid Usage

those with complete or near-complete vision loss, while individuals with partial vision loss often rely on devices that enhance existing visual capabilities.

Analysis of Reported Problems

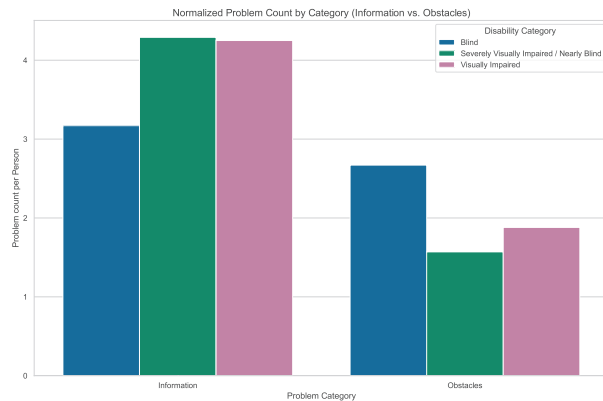


Figure 5: Normalized Problem Count by Category (Information vs. Obstacles)

Figure 5 presents the average number of challenges per participant in each vision-loss category, divided into information-related issues and physical obstacles. Severely visually impaired or nearly blind users report the highest mean number of information challenges, followed by the visually impaired group, with blind participants reporting the fewest information-related problems. By contrast, obstacle-related difficulties are most pronounced for blind users, while visually impaired and severely visually impaired participants encounter fewer physical barriers. These normalized results underscore that, although physical obstacles remain significant – especially for fully blind individuals – the greatest and most pervasive need lies in improving information accessibility, a need felt most acutely by those with intermediate vision loss.

Figure 6 offers a detailed breakdown of problem areas by disability category, illustrating how the severity of visual impairment shapes the types of challenges encountered. For blind participants, difficulties were most prevalent in closed space information and traffic obstacles, with traffic information issues also being notably significant. Those in the severely visually impaired / nearly blind group reported the highest concentration of challenges related to traffic information, underscoring the critical need for improved wayfind-

ing and communication tools in dynamic, outdoor environments. Meanwhile, visually impaired individuals faced their most significant challenges with closed space information (over 30%) and traffic information (over 25%). Also, as visual impairment worsens, physical obstacles become increasingly problematic, peaking in frequency among blind participants. These patterns show that different levels of vision loss create distinct needs for accessing information and navigating environments, underscoring the importance of personalized, context-aware assistive technologies. As visual impairment becomes more severe, physical obstacles pose greater challenges, reaching their highest impact among participants who are blind.

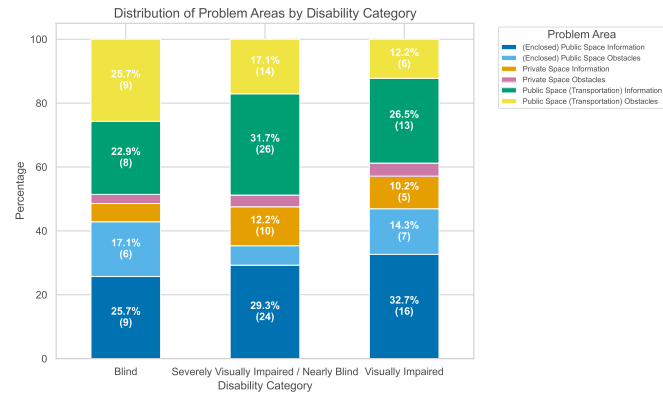


Figure 6: Distribution of Problem Areas by Disability Category

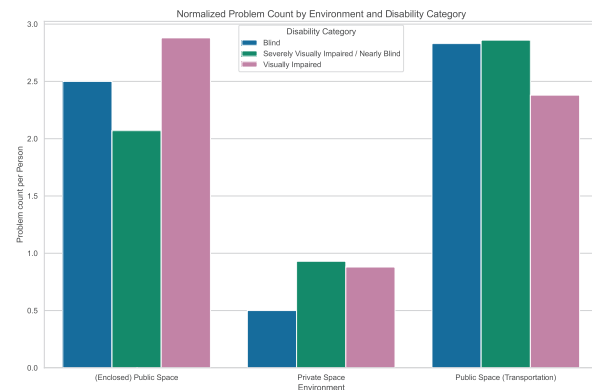


Figure 7: Normalized problem count by Disability Category and Environment

Criticism of currently available aids

In the past, participants used various assistive tools that they have since discontinued for several reasons, which will be discussed below.

One assistive device that saw moderate use in the past ($n=3$) was the vibration belt. However, participants reported that it lacked the precision needed for reliable directional guidance, making it impractical for everyday use. This perceived unreliability led to a lack of trust, ultimately contributing to the device falling out of use. Moreover, its optical appearance was often considered unaesthetic and embarrassing, further discouraging continued use.

Thirteen people currently use intelligent reading glasses as a current assistive device – yet most of these users voiced strong criticism and now scarcely use them. They found smartphones to be a more effective solution, thanks to faster operation and considerably longer battery life. In practice, the intelligent reading glasses often fell short of expectations in terms of reliability and ease of use.

A third assistive tool previously used by some participants ($n=3$) was edge filter glasses, designed to enhance contrast by filtering specific wavelengths of light. However, their usefulness was limited to certain conditions, and many participants stopped using them due to their ineffectiveness in variable lighting. In low-light environments, for example, the glasses offered little benefit, as there wasn't enough contrast to enhance.

Wishes for Future Assistive Tools

During our interviews, the blind and visually impaired participants expressed clear preferences regarding future technologies. The priority was less on complex devices and more on practical tools combining multiple functionalities that could simplify daily life, provide greater safety, and promote independence. Participants described various scenarios – from navigating public spaces to locating misplaced objects – that illustrate how appropriate technological support could contribute to greater autonomy. Below, we present the aspects identified by participants as particularly relevant.

Navigation and Orientation

Our study showed that everyday navigation was the top priority for all visually impaired participants. They desire a device that func-

tions like a reliable companion, providing precise information about the immediate surroundings, a pedestrian crossing, a dangerous intersection or orientation in big open places. Additionally, the need for timely real-time warnings such as "Caution, a car is approaching from the left" was frequently mentioned. This goes beyond simple directions, it's about a fundamental sense of security.

Obstacle and Object Recognition

It also became apparent that obstacle detection represented another crucial priority. Participants recounted regular challenges with hazards such as discarded e-scooters on walkways, temporary construction barriers, or low-hanging branch obstacles that conventional assistive tools like white canes frequently fail to detect.

Beyond simple hazard avoidance, participants showed significant interest in an "object finder" functionality, a tool to help locate misplaced everyday items such as keys or remote controls.

Everyday Assistance

Our study revealed significant challenges with daily activities. Participants desired technology that provides immediate audio information of signs or documents, eliminating the need to request assistance. Shopping emerged as particularly problematic, with product identification causing frequent uncertainty. The core desire is to reduce anxiety in seemingly minor moments, finding addresses or selecting items from shelves, and make these tasks more manageable.

Feedback Preferences

Three different feedback channels were considered: haptic, auditory, and verbal alerts. Haptic feedback is primarily used for warnings, with the intensity encoding the level of danger. Auditory feedback consists of short alerts designed to convey information quickly and effectively. A strong preference was expressed for a modular approach, allowing the system to adapt to different situations and individual preferences. For example, vibration-based feedback proves particularly useful in noisy environments where auditory alerts might be difficult to perceive or could impose a way of distracting the user in dangerous situations, whereas verbal feedback can be advantageous when precise localization of an object is required. Additionally, combining multiple feedback channels could further enhance the overall effectiveness of the system.

Discussion

This study shows that digital tools, especially smartphone apps (see Figure 1), are now the most popular aids among visually impaired people, because of their seamless integration into daily life, affordability and many built-in features like VoiceOver. In simple terms, while guide dogs and white canes remain useful, modern digital devices help users with everyday challenges like navigating busy streets and detecting obstacles or reading out text.

The study involved 30 visually impaired individuals who shared their experiences in interviews. The study used a clear qualitative content analysis method based on a category system to group common themes from these interviews. Participants explained their daily struggles like crossing streets, avoiding hazards, and performing close-range tasks such as reading signs.

Additionally, most participants owned Apple products due to their comprehensive accessibility features, such as VoiceOver, magnification tools, and customizable display settings, which are seamlessly integrated into the iOS ecosystem. The reliability and ease of use of these built-in features make Apple devices particularly attractive to visually impaired users, further contributing to the widespread adoption of digital tools. Other smartphone manufacturers are catching up (Leigh, 2017). As technology continues to evolve, digital solutions are likely to play an even greater role in enhancing accessibility and independence for individuals with visual impairments.

Inconsistencies regarding the protocolation and interpretation of the interview arose due to 8 different people from different academic backgrounds and age groups conducting, transcribing and interpreting the interviews. Thus, demographic data wasn't always recorded and only 24 interviews were transcribed word-by-word while 6 were documented by detailed note taking.

Considering the study size of 30 people, the distribution of impairments within the spectrum was unequally distributed with 21,4% of all participants being completely blind, 28,6% having a significant amount of eyesight left and 50% being almost completely blind.

Given the average age of 55.3 years, the results primarily reflect the opinions, values, and experiences of an older demographic,

which may introduce bias. However, since the average age of visually impaired individuals is generally high (Berufsverband der Augenärzte Deutschlands e.V., n.d.), this bias is difficult to avoid, but still influences the results since older people tend to be more sceptical of modern technologies.

In conclusion, while the study highlights the growing importance of digital tools for visually impaired individuals, more research is needed to create devices that are practical and reliable. By combining the best of all available technologies, future assistive tools could make daily life much easier and safer for those with visual impairments.

Summary and Future Goals

The conducted study offered an analysis of the challenges facing blind and visually impaired individuals, with a specific focus on near-work activities such as traveling by public transport. The study was grounded on 30 face-to-face and online semi-structured interviews, with participants distributed throughout Germany. The qualitative data obtained were coded using MAXQDA, allowing systematic coding and determination of salient themes regarding common challenges faced by the target population.

Key findings of the study were concentrated on the use of assistive devices. Technological devices, and in this case mainly smartphone applications, dominated the field as they were cost-effective and convenient to integrate into daily activities. Despite the superiority of the technology, traditional devices like white canes or guide dogs still provide value to the lives of the visually impaired. This suggests there may be a gap that could be addressed with AI-powered aids.

A primary area for improvement was navigation and orientation within complex urban environments, which remains a significant barrier for individuals who are blind. "Direct attention" was also highlighted in areas such as object and obstacle detection, as well as assistance with tasks like shopping – primarily due to the anxiety and uncertainty these situations can cause. These areas clearly represent opportunities where AI-based tools could provide effective solutions.

Prospectively, developing a functional prototype that leverages the capabilities of Artificial Intelligence could significantly address the

challenges faced by the visually impaired. This prototype should ideally integrate the strengths of traditional, digital, and intelligent tools into a user-friendly solution tailored to their needs.

The initial form factor for deployment is likely to be a smartphone application, given the widespread familiarity and usage of smartphones among the target group. Over time, this may be extended through integration with an AI-powered wearable device to further enhance functionality and user experience. The prototype should prioritize improved navigation by providing precise environmental information, timely alerts for potential hazards, and reliable object and obstacle recognition. Safety-critical features such as real-time object detection, obstacle avoidance, and tailored route guidance are essential to ensure the device acts as a dependable companion that maximizes user safety.

Interview results further emphasize the importance of a modular feedback system that adapts to varying real-world scenarios. Instead of a one-size-fits-all approach, the prototype should combine haptic, auditory, and verbal cues, dynamically adjusting based on context. For example, in noisy environments where auditory feedback may be ineffective, the system could switch to haptic notifications, and vice versa. This flexible feedback mechanism is crucial to maintaining effective communication and enhancing the overall user experience.

Ultimately, such a device would represent a major leap toward a more inclusive, technology-driven society – one that empowers visually impaired individuals with greater independence and quality of life. The development of this prototype is not just a technical milestone, but a step toward realizing a broader, more equitable future. ■

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Process description

InsEYEght

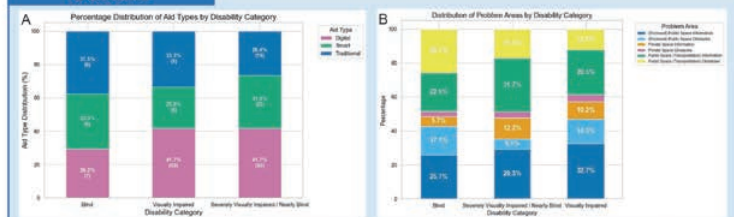


Bridging technology and accessibility to empower the visually impaired.

Summary

Our research explored how **AI-powered** wearable technologies can close the gap in mobility and independence for **blind and visually impaired individuals**. Based on **30 semi-structured interviews** across Germany, key challenges and needs were identified. While white canes remain essential and smartphone apps are becoming more common, many opportunities exist to **improve independence** with AI-powered solutions designed for users' needs.

Outcome



Panel A: Aid preferences vary by disability group. **Blind** participants use mostly **traditional tools** (37.5%), such as canes, while **(severely) visually impaired** primarily rely on **digital aids**, like apps (41.7%). Overall, digital tools are the most frequently used.

Panel B: The **severity** of visual impairment influences the challenges faced. For instance, **blind** participants struggle most with **closed space** and **traffic obstacles**, while participants with fewer visual impairment seem to struggle more with **public space information**.

Impact - Raising Awareness

At the heart of our project lies the belief that participation, connection, and independence are fundamental features for the sense of belonging to the human society. Many blind and visually impaired individuals expressed the desire to **"take part in life again"**, to move freely, engage socially, and live independently. Our research sheds light on the barriers they face in daily life and highlights the need for more inclusive solutions.

Research Life Cycle



Acknowledgments

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Our initial idea was to use AI to increase efficiency in the healthcare sector – under the team name EfficiAID. We quickly realized that legal and structural complexity limited real impact. A second idea, an AI chatbot to replace GP visits, seemed feasible due to clear diagnostic criteria but was dismissed as similar solutions already exist.

A breakthrough came with the idea of AI-powered smart glasses for visually impaired users. This raised essential questions: What are the hardware and software requirements? What are the real challenges users face in everyday environments – private spaces, traffic, public buildings? What accidents still happen, which aids are used, and what criticism exists?

To answer these, we pivoted to our final idea and re-named the team InsEYEght. Our focus shifted to user research through semi-structured interviews. This covered literature reviews, a flexible questionnaire, and contact with several self-help groups. Interviews were conducted, transcribed, and systematically analyzed. The resulting insights revealed real-world needs that now shape our project.

Outlook: These insights form the foundation for future prototype development, ensuring solutions are rooted in actual user challenges.

Self-Reflection insEYEght



Johannes
joined :)

Monica & Martin
joined :)



Lab Tour by Johannes



Visiting the SightCity in Frankfurt



Planning Interviews



Data evaluation Workshop
by Monica



Final Team-Building

Our Team-Journey