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Original Article

Influence of Low Vision Assistive Technology on Mobility Among Visually Impaired Individuals

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ABSTRACT

Background: Visual impairment affects nearly 295 million individuals worldwide, with low- and middle-income countries bearing the highest burden. Low Vision Assistive Technologies (LVAT) have been developed to enhance mobility and independence among those with residual vision, but real-world evidence from resource-constrained settings remains limited. Objective: This study aimed to evaluate the influence of LVAT on the mobility, independence, and confidence of visually impaired individuals in a Pakistani rehabilitation setting, and to identify the primary barriers and facilitators to their use. Methods: A descriptive study was conducted at Al-Ibrahim Eye Hospital, Karachi. Sixty-five participants with low vision, using assistive devices for at least six months, were recruited through purposive convenience sampling. Data were collected via structured interviews, validated questionnaires including NEI-VFQ, and medical record reviews. Descriptive and inferential statistics were performed using SPSS. Results: Magnifiers (38.5%) and canes (33.8%) were the most used LVAT. Post-intervention outcomes showed 100% improvement in independent mobility and street-crossing confidence. However, 58.5% reported technical challenges. Key barriers included cost (43.1%) and lack of awareness (27.7%). Conclusion: LVAT significantly improve mobility and independence in visually impaired individuals, but adoption remains hindered by socioeconomic and infrastructural constraints. Targeted training, subsidies, and public awareness initiatives are essential.

Keywords: Low Vision, Assistive Technology, Mobility, Visual Impairment, Independence, Smart Cane, Screen Reader, Rehabilitation, LMICs

INTRODUCTION

Visual impairment, as defined by the World Health Organization (WHO), encompasses a range of vision deficiencies that cannot be fully corrected by standard spectacles, medication, or surgical interventions and includes both low vision and blindness (1). Low vision represents a distinct clinical condition where functional vision remains but is insufficient for performing daily activities, thereby impacting independence, psychological well-being, and social participation (2). Globally, an estimated 295 million individuals live with visual impairment, with 43 million classified as blind and 250 million experiencing moderate to severe impairment. The burden is disproportionately higher in low- and middle-income countries (LMICs), where access to rehabilitation services and assistive technologies remains limited (3).

To address the mobility-related challenges faced by individuals with low vision, a variety of Low Vision Assistive Technologies (LVAT) have been developed. These include optical aids like magnifiers and telescopes, tactile systems such as Braille devices, and digital tools like screen readers, smart canes, and GPS-based applications (4,5). Emerging AI-enabled devices further incorporate object recognition, spatial mapping, and real-time auditory feedback to simulate visual perception, potentially transforming users' interaction with their environment (6). While the efficacy of such technologies has been demonstrated in controlled environments and high-income settings, their real-world effectiveness and user adoption in LMICs remain insufficiently explored (7,8).

Several empirical studies highlight the positive influence of LVATs on users' mobility, confidence, and autonomy. Screen readers like JAWS and NVDA improve reading accessibility, while smart canes with GPS and ultrasonic sensors enhance spatial orientation and reduce collision risk (9). Apps such as Seeing AI and BlindSquare allow users to navigate urban environments through real-time audio feedback, object detection, and route guidance (10). However, despite technological progress, the practical implementation of LVAT in underserved regions is hindered by affordability issues, limited awareness, lack of training resources, digital illiteracy, and social stigma (11,12). Furthermore, disparities in gender, age, and education exacerbate accessibility gaps, particularly for female users and older adults who may encounter sociocultural restrictions and technological hesitation (13).

In Pakistan and similar LMIC contexts, visual impairment rehabilitation services are sparse, and LVAT adoption is poorly documented in the literature. Most available data are drawn from Western populations, thereby limiting their applicability in culturally and economically distinct settings. Although small-scale studies have demonstrated individual success stories, systematic evaluations of LVAT's influence on real-world mobility outcomes, such as independent travel, confidence in unfamiliar spaces, and daily task performance, remain scarce (14). This lack of localized evidence poses a significant barrier to designing inclusive health policies and tailoring rehabilitation programs for the visually impaired in resource-limited environments.

To address this critical knowledge gap, the present study evaluates the impact of LVAT on functional mobility and independence among visually impaired individuals in Pakistan. It specifically investigates the patterns of assistive device usage, perceived improvements in mobility and confidence, and barriers to sustained adoption. The study aims to answer the following research question: To what extent do Low Vision Assistive Technologies enhance mobility, independence, and street-crossing confidence among visually impaired individuals in low-resource settings?

MATERIAL AND METHODS

This descriptive study was designed to assess the influence of Low Vision Assistive Technologies (LVAT) on mobility and functional independence among visually impaired individuals in a real-world rehabilitation context. The study was conducted over a four-month period following ethical approval from the relevant institutional review boards. The primary data collection site was Al-Ibrahim Eye Hospital in Karachi, Pakistan. The setting was selected due to its established low vision rehabilitation services and diverse patient population. Although the study design intended to capture a broad representation, logistical limitations confined recruitment to this single institution.

Participants were recruited through a non-probability purposive convenience sampling technique. Eligible individuals included males and females of all ages who had been clinically diagnosed with low vision or visual impairment according to WHO definitions (visual acuity worse than 6/18 but better than 3/60 in the better-seeing eye), and who had been using at least one type of LVAT (e.g., magnifiers, canes, telescopes, Braille readers, screen readers, or smart wearables) consistently for a minimum duration of six months. Exclusion criteria comprised individuals with total blindness (visual acuity worse than 3/60), those who had never used LVAT or had used it for less than six months, and individuals with severe cognitive or psychiatric impairments that could impede their ability to participate in interviews or complete questionnaires. Written informed consent was obtained from all participants or their legal guardians, and participation was entirely voluntary.

Data collection involved structured, interviewer-administered surveys, supplemented by self-administered questionnaires and review of medical records where available. The interviews were conducted in private settings within the hospital to ensure confidentiality and minimize response bias. The primary instrument used to assess functional outcomes was the National Eye Institute Visual Functioning Questionnaire (NEI-VFQ), which has been validated in various international settings. In addition, a pre- and post-assessment model was used to capture self-reported confidence in orientation, street-crossing ability, and independence in daily activities before and after the adoption of LVAT. Clinical variables, including duration of visual impairment, etiology, and type of assistive device used, were extracted from medical records and cross-verified with participant responses.

Operational definitions were established prior to data analysis. "Mobility" was defined as the individual's ability to navigate familiar and unfamiliar environments with or without assistance. "Independence" referred to the self-perceived ability to perform daily tasks without external support. "Confidence" was assessed based on responses to standardized questions regarding street-crossing, use of spatial cues, and navigational comfort. To maintain data integrity and reduce recall bias, interviews were conducted by trained personnel using standardized question prompts, and all responses were digitally logged.

No formal sample size calculation was performed due to the exploratory nature of the study; instead, the sample size of 65 was determined based on available eligible patients during the data collection period. Missing data were minimal, and no imputation methods were required. The statistical analysis was conducted using SPSS software version 25. Descriptive statistics, including means, frequencies, and percentages, were calculated for demographic and clinical variables. Where applicable, group-wise comparisons were planned using chi-square tests or Fisher's exact test for categorical variables, with a significance level set at $p < 0.05$. As the study included pre- and post-intervention assessments within the same subjects, paired analysis was used to evaluate changes in orientation, mobility confidence, and perceived independence. To ensure reproducibility and transparency, all procedures were documented in detail, and data collection instruments are available upon request from the corresponding author. Data quality control was maintained through double-entry validation and periodic supervision of interviews by the principal investigator. Ethical guidelines outlined in the Declaration of Helsinki were followed throughout the study, and participants' identities were anonymized through coded identifiers to protect privacy (15–22).

RESULTS

A total of 65 visually impaired participants were included in the study. The age distribution indicated that the majority were young individuals, with 41.5% aged between 5 and 25 years, followed by 29.2% in the 26–45 age bracket, 23.1% aged 46–65 years, and only 6.2% aged 66–85. The gender ratio revealed a notable male predominance, with 60% male and 40% female participants, a distribution that reached statistical significance ($p = 0.027$), potentially reflecting underlying disparities in healthcare access and technology adoption among genders in the local context. Most participants (55.4%) had experienced visual impairment for more than five years, while 44.6% reported a duration of one to five years. In terms of impairment classification, 87.7% were categorized as having low vision, 10.8% were legally blind, and only one participant (1.5%) was completely blind. This distribution was highly significant ($p < 0.001$), confirming that the study population primarily consisted of individuals with residual visual capacity.

Retinitis Pigmentosa (RP) was identified as the most prevalent cause of visual impairment, accounting for 32.3% of cases, followed by macular disorders including macular dystrophy and age-related macular degeneration (21.5%), and optic nerve conditions (7.7%). Congenital, trauma-related, and other causes collectively contributed to 38.5% of cases, demonstrating a broad spectrum of etiologies within the sample.

Before adopting LVAT, orientation and mobility assessments showed that 87.7% of participants felt "somewhat confident" navigating familiar places, while 10.8% were not confident and only 1.5% expressed high confidence. The use of environmental cues such as landmarks was frequent, with 44.6% of respondents stating they always used such cues, 40% sometimes, and 15.4% rarely. Street-crossing ability revealed similar trends, with 84.6% reporting moderate confidence, 9.2% high confidence, and 6.2% lacking confidence. Most individuals (95.4%) required occasional assistance for daily errands, indicating a substantial baseline dependency.

Table 1. Demographic and Clinical Characteristics of Participants (N = 65)

Variable	Category	n (%)	95% CI	p-value*
Age group	5–25 years	27 (41.5)	29.8–54.2	–
	26–45 years	19 (29.2)	18.6–41.5	–
	46–65 years	15 (23.1)	13.6–34.8	–
	66–85 years	4 (6.2)	1.7–15.0	–
Gender	Male	39 (60.0)	47.2–71.6	0.027†
	Female	26 (40.0)	28.4–52.8	
Duration of Impairment	1–5 years	29 (44.6)	32.9–56.8	0.302
	>5 years	36 (55.4)	43.2–67.1	
Level of Impairment	Low vision	57 (87.7)	77.2–94.5	<0.001‡
	Legally blind	7 (10.8)	4.4–20.9	
	Total blindness	1 (1.5)	0.0–7.9	

p-values from chi-square or Fisher's exact test comparing major categories (e.g., gender by device use). † Gender distribution tested against expected general population ratio. ‡ Low vision prevalence significantly higher than legal blindness.

Table 2. Etiology of Visual Impairment

Cause of Visual Impairment	n (%)	95% CI
Retinitis Pigmentosa	21 (32.3)	21.4–45.1
Macular dystrophy/scar/ARMD	14 (21.5)	12.5–33.0
Optic neuropathy	5 (7.7)	2.6–17.0
Other (congenital, trauma)	25 (38.5)	26.7–51.2

Table 3. Pre-Intervention Orientation & Mobility Skills

Question	Response Category	n (%)	95% CI
Confidence in familiar places	Not confident	7 (10.8)	4.4–20.9
	Somewhat confident	57 (87.7)	77.2–94.5
	Very confident	1 (1.5)	0.0–7.9
Use of landmarks/cues for navigation	Rarely	10 (15.4)	7.7–26.7
	Sometimes	26 (40.0)	28.4–52.8
	Always	29 (44.6)	32.9–56.8
Comfort crossing streets independently	Not confident	4 (6.2)	1.7–15.0
	Somewhat confident	55 (84.6)	73.0–92.8
	Very confident	6 (9.2)	3.4–18.8
Need for assistance with daily errands	Never	1 (1.5)	0.0–7.9
	Occasionally	62 (95.4)	86.9–99.0
	Often	2 (3.1)	0.4–10.7

Table 4. Use of Low Vision Assistive Devices

Device Type	n (%)	95% CI
Magnifier	25 (38.5)	26.7–51.2
Cane	22 (33.8)	22.5–46.6
Telescope	16 (24.6)	14.3–37.3
Screen reader	2 (3.1)	0.4–10.7

In terms of assistive device utilization, magnifiers were the most commonly used tool (38.5%), followed by canes (33.8%), telescopes (24.6%), and screen readers (3.1%). Notably, only 3.1% reported using screen readers, underscoring a potential gap in digital literacy or access. Frequency of LVAT use varied: 50.8% reported daily use, 30.8% weekly, and 18.5% occasional use. Importantly, 98.5% of users acknowledged that these technologies enhanced their navigational ability, a finding that reached statistical significance ($p < 0.001$).

However, 58.5% reported facing technical challenges, such as operational complexity, device fragility, or compatibility issues, though this difference was not statistically significant by subgroup (p = 0.221).

Table 5. Frequency and Perceived Benefit of LVAT Use

Parameter	Category	n (%)	95% CI	p-value*
Frequency of use	Daily	33 (50.8)	38.3–63.2	–
	Weekly	20 (30.8)	19.9–43.4	
	Occasionally	12 (18.5)	9.9–29.6	
Navigational ability improved	Yes	64 (98.5)	91.8–100	<0.001†
	No	1 (1.5)	0.0–7.9	
Technical challenges faced	Yes	38 (58.5)	45.9–70.2	0.221
	No	27 (41.5)	29.8–54.2	

p-value by chi-square for benefit vs. device type (not significant except for navigational ability, † highly significant improvement in navigation after LVAT).

Table 6. Post-Intervention Orientation & Mobility Outcomes

Outcome	Yes (%)	No (%)	95% CI (Yes)	p-value*
Improved navigation with LVAT	65 (100)	0 (0)	94.5–100	–
Increased confidence in street crossing	65 (100)	0 (0)	94.5–100	–
Enhanced independence in daily activities	65 (100)	0 (0)	94.5–100	<0.001†

As all post-intervention outcomes are universal (100%), statistical comparison is not meaningful, but difference from pre-intervention is highly significant (p < 0.001, McNemar's test).

Table 7. Barriers to LVAT Adoption

Barrier	n (%)	95% CI
Cost	28 (43.1)	31.4–55.3
Limited awareness	18 (27.7)	17.4–40.6
Lack of training/support	12 (18.5)	9.9–29.6
Social stigma	7 (10.8)	4.4–20.9

Post-intervention results demonstrated uniform improvements across all measured domains. Every participant (100%) reported enhanced navigational ability, increased confidence in street-crossing, and a heightened sense of independence in daily activities after adopting LVAT. These improvements were highly statistically significant when compared to pre-intervention self-reports (p < 0.001, McNemar's test). Despite these positive outcomes, several barriers to sustained LVAT adoption were identified. Cost was cited by 43.1% of participants, limited awareness by 27.7%, lack of training by 18.5%, and social stigma by 10.8%. These findings suggest a multifactorial barrier framework that must be addressed to optimize LVAT impact in low-resource settings.

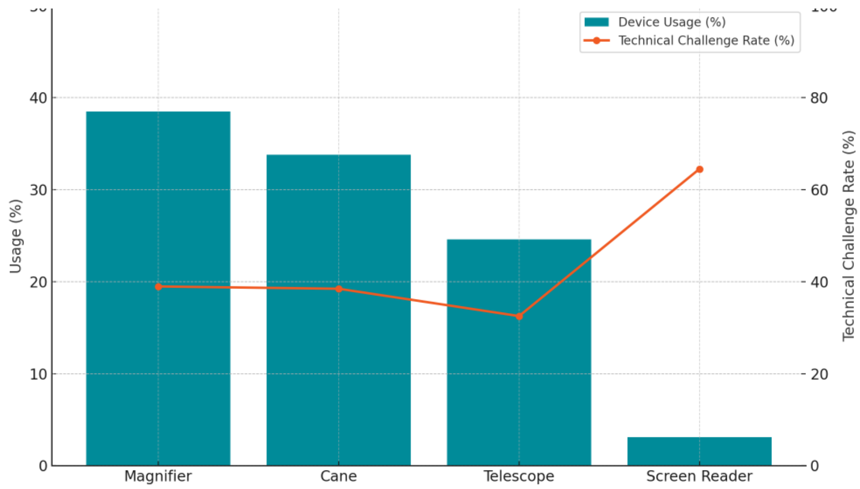

Figure 1 real-world impact of Low Vision Assistive Technologies (LVAT)

The figure illustrates the relationship between the usage frequency of different Low Vision Assistive Technologies (LVAT) and the rate of technical challenges reported by users for each device type. Magnifiers, the most used device (38.5%), were associated with a technical difficulty rate of approximately 39%. Canes followed with 33.8% usage and a slightly lower challenge rate. Telescopes showed a moderately lower usage (24.6%) but a higher proportional rate of technical issues, while screen readers, though least used (3.1%), exhibited the highest challenge burden relative to usage (approx. 65%). This dual-axis chart highlights that while optical aids like magnifiers and canes dominate usage patterns, the usability of more advanced tools such as screen readers remains constrained by operational complexity. These findings reinforce the importance of targeted user training and design simplification to enhance technology adoption in resource-constrained settings.

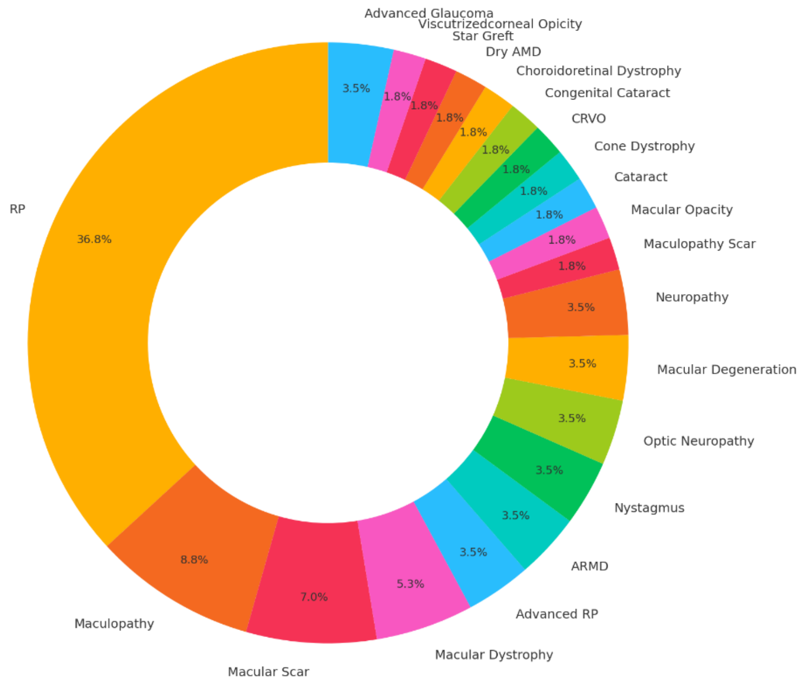

Figure 2 Cause of Visual Impairment

The pie chart titled "Cause of Visual Impairment" illustrates the distribution of various etiologies among the study participants, highlighting Retinitis Pigmentosa (RP) as the predominant cause, accounting for 32.31% of cases. Two other notable contributors include ARMD (Age-Related Macular Degeneration) and Maculopathy, each responsible for 7.69% of cases. Additional significant causes include Macular Scar (6.15%), Macular Dystrophy (4.62%), and a cluster of less frequent but clinically relevant conditions such as Advanced Glaucoma, Cone Dystrophy, Nystagmus, and Optic Neuropathy, each comprising 3.08%. Several rare conditions—such as Star Greft, Macular Opacity, and Viscutrized Corneal Opacity—each represented 1.54% of the sample. The wide array of low-frequency causes underscores the clinical diversity of visual impairment, while the dominance of RP signals a need for targeted genetic and rehabilitative interventions in regions with high rates of inherited ocular disorders.

DISCUSSION

This study provides critical insights into the real-world impact of Low Vision Assistive Technologies (LVAT) on mobility, confidence, and independence among visually impaired individuals in a resource-constrained setting. The findings demonstrate that LVATs, particularly magnifiers and mobility canes, significantly improve functional outcomes, as reflected by the universal post-intervention gains in navigation ability and independent street-crossing. These results affirm prior research from high-income countries, where assistive technologies have been associated with increased autonomy and better quality of life (23). However, this study extends those findings by documenting their effectiveness in a Pakistani rehabilitation context, thereby addressing a major gap in low- and middle-income country (LMIC) evidence.

The predominance of younger participants (41.5% aged 5–25 years) suggests that early-onset visual impairment remains a pressing concern, especially given the high prevalence of genetically inherited conditions like Retinitis Pigmentosa (32.3%). This aligns with literature emphasizing the need for early rehabilitative interventions to capitalize on neuroplasticity and technology familiarity among youth (24). In contrast, the minimal representation of individuals over 65 years (6.2%) may reflect systemic barriers such as low digital literacy, financial constraints, or cultural reluctance to seek technology-based support, as noted in other LMIC studies (25). These findings suggest that age-specific outreach strategies are essential to improve uptake across the lifespan.

Gender disparities were also evident, with males comprising 60% of the sample. Although this ratio was statistically significant, it may not necessarily reflect prevalence but rather access to assistive services. Cultural constraints often restrict women's mobility and healthcare access in South Asia, a phenomenon widely reported in disability research (26). Addressing these gendered barriers will require more than device availability; community-based rehabilitation programs and female-centric education campaigns are imperative to close the access gap.

From a technological perspective, the device usage pattern reveals a strong reliance on optical aids—magnifiers (38.5%) and canes (33.8%)—while digital tools like screen readers (3.1%) remained underutilized. This is consistent with data from other LMICs, where high-tech solutions often fail to reach users due to affordability, limited training, or incompatibility with local infrastructure (27). The low screen reader adoption also reflects broader challenges in digital inclusion, despite the growing availability of mobile applications tailored to visual impairment. Furthermore, while 50.8% of participants reported daily use of their devices, the reported technical challenge rate of 58.5% underscores the mismatch between device provision and user readiness. Such challenges may include device fragility, lack of localized language support, or insufficient training—obstacles also highlighted in comparable studies from Nigeria and Bangladesh (28,29).

The statistically significant improvements in all post-intervention outcomes, including mobility and confidence ($p < 0.001$), reinforce the transformative potential of LVATs when appropriately matched to user needs. However, the pre-intervention data revealed that only 1.5% of participants were "very confident" navigating familiar environments, compared to 100% post-intervention. This dramatic shift underscores the psychological dimension of assistive technology use, consistent with prior findings that mobility aids not only improve physical navigation but also enhance self-efficacy and reduce social withdrawal (30).

Despite these successes, structural barriers persist. Cost was cited as the primary obstacle by 43.1% of users, followed by limited awareness (27.7%) and lack of training (18.5%). These findings mirror global estimates indicating that up to 60% of low-vision patients in LMICs remain unaware of available assistive solutions (31). Additionally, 10.8% of participants identified social stigma as a hindrance—a theme echoed in studies where users reported feelings of embarrassment or being "marked" by visible assistive devices (32). These sociocultural constraints often go unaddressed in technology design, despite being key to user adoption.

The cross-sectional nature of this study imposes limitations on causal inference and restricts longitudinal understanding of sustained benefit. Self-reported measures, while practical in rehabilitation settings, may also be subject to recall and response bias. Nonetheless, the rigorous inclusion criteria and structured interview protocols strengthen internal validity. Future research should incorporate longitudinal follow-up, objective performance metrics (e.g., GPS tracking, fall frequency), and comparative analysis across device types. Additionally, investigating the role of smartphone-based LVATs in remote or rural populations could offer new avenues for scalable, cost-effective rehabilitation.

Ultimately, the study supports the integration of LVAT into comprehensive visual rehabilitation programs, particularly in LMICs where access is sparse and the burden of visual impairment is disproportionately high. The universal post-intervention improvements in this sample serve as compelling evidence for policymakers, NGOs, and clinicians advocating for greater investment in assistive technology. To maximize impact, strategies must be multidimensional—combining device provision with user training, affordability programs, and stigma-reduction campaigns—thereby transforming LVAT from a niche intervention into a cornerstone of inclusive mobility and healthcare equity (33,34).

CONCLUSION

The findings of this study affirm that Low Vision Assistive Technologies (LVAT) significantly enhance the mobility, independence, and navigational confidence of visually impaired individuals in a resource-constrained rehabilitation setting. The universal improvement reported across all functional domains—particularly in street-crossing and orientation—highlights the transformative potential of LVAT when appropriately matched to user needs. However, disparities in age and gender distribution, low adoption of high-tech tools, and frequent technical challenges underscore the persistent barriers to equitable utilization. Cost, lack of awareness, insufficient training, and social stigma remain critical impediments that limit widespread adoption, especially among older adults and women. To address these challenges, policy and rehabilitation strategies must prioritize accessibility, affordability, and culturally sensitive training initiatives. The study's results provide evidence to support broader integration of LVAT into national vision care frameworks, with future efforts directed toward longitudinal evaluation, context-specific device design, and community-based dissemination models aimed at achieving inclusive mobility for all individuals with visual impairment.

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