# Nafath
by Mada

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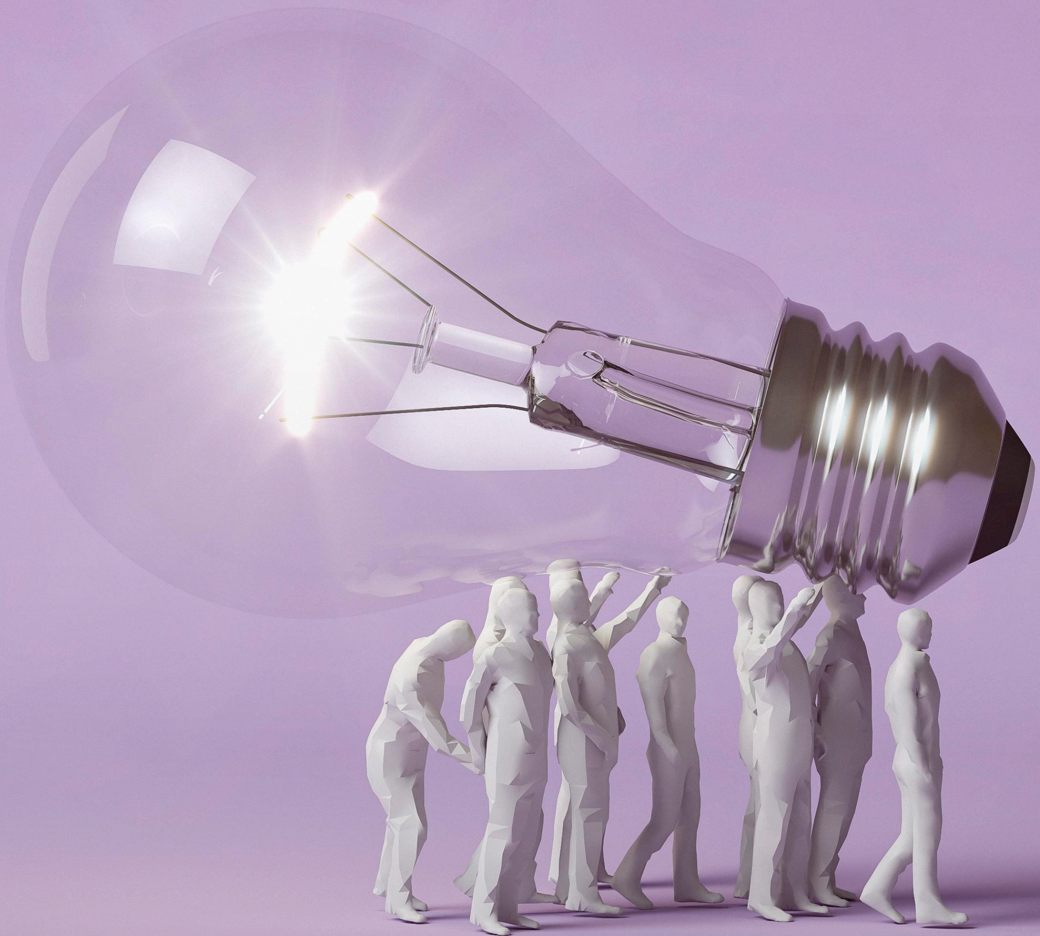

## Innovating Inclusion
Bridging Research, Community & Technology



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# About Mada

Mada – Assistive Technology Center Qatar, is a private institution for public benefit, which was founded in 2010 as an initiative that aims at promoting digital inclusion and building a technology-based community that meets the needs of persons with disabilities (PWDs). Mada today is the world's Center of Excellence in digital accessibility in Arabic.

The Center works through smart strategic partnerships to enable the education sector to ensure inclusive education, the community sector through ICTs to become more inclusive, and the employment sector to enhance employment opportunities, professional development and entrepreneurship for persons with disabilities.

The Center achieves its goals by building partners' capabilities and supporting the development and accreditation of digital platforms in accordance with international standards of digital accessibility. Mada also raises awareness, provides consulting services, and increases the number of assistive technology solutions in Arabic through the Mada Innovation Program to ensure equal opportunities for the participation of persons with disabilities in the digital society.

# About Nafath

**Nafath aims to be a key information resource for disseminating the facts about latest trends and innovation in the field of ICT Accessibility. It is published in English and Arabic languages on a quarterly basis and intends to be a window of information to the world, highlighting the pioneering work done in our field to meet the growing demands of ICT Accessibility and Assistive Technology products and services in Qatar and the Arab region.**

# Content Page







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# Open call for papers

**“Nafath” an open access journal, solicits original research contributions addressing the accessibility, usability, and key information resource for disseminating the facts about latest trends and innovation in the field of ICT Accessibility to enable persons with disability and the elderly. Nafath is focusing on the theoretical, methodological, and empirical research, of both technological nature, that addresses equitable access and activate participation of potentially all citizens in Information Society.**


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- Adaptable and adaptive interfaces
- Alternative and augmented Input /Output techniques
- Applications of assistive technologies in the mainstream
- Architectures, development methods and tools for ICT Accessibility
- Design for All and accessibility education and training
- Evaluation of Accessibility, Usability, and User Experience
- Innovative Assistive applications and environments and ICT Accessibility solutions
- Localization
- Novel designs for the very young, the elderly, and people with different types of disabilities
- Novel interaction techniques, platforms, metaphors, and devices
- Personalization techniques and personalized products and services
- Smart artifacts, smart cities and smart environments
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# Autistic Children's Emotional Engagement in a Virtual Flight Environment

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**Abstract** - This study explores how virtual reality (VR) can help children with autism better manage the emotional challenges of air travel. Five children on the autism spectrum participated in an immersive VR flight simulation designed to mimic the real experience of flying. Emotional responses were observed before, during, and after the session, and insights were gathered through detailed interviews and structured observations involving both the children and their families. The results highlight VR's potential as a powerful tool for experiential learning, helping children feel more at ease and emotionally prepared for travel-related stress. While the simulation offered a realistic aviation experience, the findings point to a need for more varied and complex scenarios to fully prepare children for the unpredictability of real-life events. Overall, this research supports the growing role of VR as a supportive technology for autistic children, helping them build emotional readiness and confidence in facing real-world situations like flying.

**Keywords**
Autism Spectrum Disorder; Virtual Reality; Assistive Technology.

## 1. Introduction

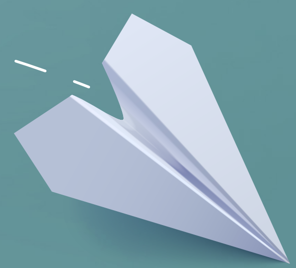
Autism spectrum disorder (ASD) is a developmental disability characterized by persistent impairments in social communication and interactions, and restricted, repetitive patterns of behavior, interests, or activities [1]. Individuals with ASD often face challenges in eye contact, understanding emotions, and forming relationships, alongside repetitive behaviors, strict routines, and unusual sensory responses [2], [3], [4]. Symptoms typically emerge in early childhood and vary in severity [1], [4], [5]. ASD has a strong genetic basis, with high family recurrence rates and differences in brain development implicated; environmental factors may also contribute, though to a lesser extent [1], [3]. Diagnosis relies on behavioral assessments, as there are no definitive medical tests [1], [6]. It affects around 1% of the population, with higher rates in males and frequent comorbidities like anxiety or intellectual disability [5], [6]. While early intervention improves outcomes, most individuals require lifelong support [2], [6].

Recent literature on autism and travel reveals a growing but still limited understanding of the unique challenges faced by autistic individuals and their families when engaging in tourism and transportation. New environments, particularly travel settings, present significant challenges for children with ASD due to heightened sensory sensitivities, a strong preference for routine, and difficulties in coping with unpredictability. Airports are often overwhelming, with bright lights, loud noises, crowded spaces, and unfamiliar social dynamics, which can trigger anxiety, distress, and behavioral difficulties [7], [8], [9]. These experiences not only impact the child but also place additional stress on families, often limiting their ability or willingness to travel [7], [8]. Studies have highlighted major barriers such as sensory overload, unpredictability, and limited support services during air travel, public transport, and family vacations [10]. Families often report heightened stress due to a lack of autism-aware travel services and environments that fail to accommodate sensory and communication needs [11], [12]. Although efforts like inclusive airport design and peer-mediated travel training show promise [13], [14], research is still sparse on systematic interventions and industry-wide strategies. A significant gap exists in exploring how different travel modes and destinations could adapt to meet autistic travelers' evolving developmental and sensory needs across the lifespan.



Current research highlights that emotion regulation (ER) is a significant challenge for individuals with autism spectrum disorder (ASD), contributing to social difficulties, behavioral problems, and co-occurring mental health conditions such as anxiety and depression. Children with autism often exhibit emotional dysregulation through meltdowns, aggression, or withdrawal, which can persist into adolescence and adulthood [15], [16]. Studies indicate that deficits in both emotional awareness and executive functioning hinder autistic individuals' ability to manage arousal and adapt behaviors in social contexts [17], [18]. Importantly, emotion dysregulation is not strongly correlated with IQ, underscoring the need for targeted interventions across cognitive levels [15]. Emerging interventions such as the Emotional Awareness and Skills Enhancement (EASE) program have shown promise in improving ER by teaching mindfulness and emotional awareness techniques [19]. Despite progress, gaps remain in scalable assessments and in adapting treatments to individual neurobiological profiles, particularly for those with demand-avoidant traits [20]. Overall, strengthening emotion regulation skills is critical for enhancing long-term outcomes in individuals with ASD. Children with ASD tend to seek predictability and are more likely to avoid unfamiliar environments that disrupt their established routines [7], [21]. In such situations, they may exhibit increased anxiety, repetitive behaviors, or emotional meltdowns [7], [8], [9], [21]. These responses reflect the broader difficulties they face in navigating new sensory and social environments [7], [8], [21].

To address these challenges, virtual reality (VR) technology has emerged as a promising intervention tool. VR is increasingly recognized as a promising simulation tool to support children with ASD, particularly in building social, communication, and daily living skills. VR provides immersive, interactive environments where autistic children can safely practice behaviors that might be overwhelming or difficult to simulate in real life, such as air travel, social interactions, or emergency responses [22]. Studies show that VR-based interventions have successfully enhanced emotional recognition, task performance, and situational preparedness in autistic children [23], [24]. For example, VR tools designed for fire safety or A disaster readiness allow autistic users to repeatedly engage in realistic decision-making tasks, improving safety awareness in a non-threatening format [25], [26]. Moreover, VR interventions have been shown to improve attention and engagement during learning, especially when combined with gamification or personalized avatars [27], [28]. VR simulations, such as airplane or airport environments offer controlled, safe, and repeatable experiences that can help desensitize children to the stressors associated with travel [29], [30]. Through repeated exposure and guided interaction, VR can enhance coping skills and promote the transfer of learned behaviors to real-world settings [29], [30]. Airports are a focal point for VR-based interventions due to their complex sensory and social demands [7], [30]. While cost and accessibility remain barriers to widespread implementation, current literature affirms VR's potential as an innovative and effective tool in autism interventions.



The present study aims to explore how children with ASD emotionally and behaviorally respond to a VR airplane simulator, with a specific focus on the airport environment. By simulating this travel experience, the study seeks to reduce anxiety, improve adaptability, and enhance travel readiness in children with ASD.

# 2. Methodology

## 2.1 Study Design

This study sets out to explore how children with ASD emotionally respond to a VR airplane simulation. Approved by the Institutional Review Board (ID#QBRI-IRB-2023-99), the research was designed to create a safe and immersive experience where participants could engage with a simulated flight environment. A qualitative approach was used to gather rich, first-hand insights through semi-structured interviews, structured observations, and brief questionnaires. This flexible methodology enabled researchers to better understand each child's unique experience and identify patterns in how they responded to the VR environment. A pre- and post-test format was applied to measure any changes in emotions, attitudes, or comfort levels before and after the simulation, offering a clear picture of the impact of the experience

## 2.2 Simulation Experience: Creating a Realistic Travel Setting

To closely mimic the experience of air travel, children were seated in airplane-style chairs facing a screen that played a video of a flight attendant delivering safety instructions and welcoming passengers. To add to the realism, a subwoofer played background airplane sounds, helping to recreate the sensory atmosphere of a real flight. For children sensitive to VR headsets, the simulation was also available in a standard screen format. The entire session lasted between two and five minutes, giving children just enough exposure to become familiar with the travel experience without feeling overwhelmed. Participants could choose whether or not to wear the VR headset, making the setup adaptable to their individual comfort levels. (See Figure 1 for a visual of the setup.)


Figure 1: The Simulation Setting



## 2.3 The Procedure

Participants for the study were selected using purposive sampling, in collaboration with Mada - Assistive Technology Center Qatar that invited eligible families. Upon arrival, families were welcomed warmly and provided with a clear explanation of the study, its purpose, duration, confidentiality measures, and their rights as participants. Informed consent was obtained from the parents or guardians, while children provided assent, affirming their willingness to participate. Before the VR experience began, families completed a short interview and questionnaire covering demographic details and prior travel experiences with their child. These interviews were audio-recorded for accuracy with the family's consent.

The study utilized Go Talk Now, an augmentative and alternative communication (AAC) device that offers voice output when images are tapped to help children express their feelings before the simulation. This tool was specifically recommended by center specialists due to the children's familiarity with it.

Each child, accompanied by a family member, then entered the simulation room for the virtual airplane experience. After exiting, they were asked to share how they felt using the same AAC device. The researcher carefully observed and recorded responses. Finally, a post-experience interview was conducted with families to capture their reflections on the VR simulator and its impact.

# 3. Result

**Feedback gathered from both children and their families during the study was analyzed using an inductive, data-driven thematic analysis approach. This method helped uncover four key themes: emotional responses, experiential learning, realism of the simulation, and suggestions for improving the VR experience.**

## 3.1 Participant Overview

A total of five children diagnosed with ASD took part in the study. To ensure confidentiality, each participant is referred to by a unique code (e.g., N1, N2, etc.). Table 1 provides a summary of participant demographics. Three children (N1, N2, N3) had prior experience with VR games, and all participants, except N2, had traveled by airplane regularly. N2 had only flown once, at nine months old. All five children chose to wear the VR headset during the simulation.

| Participant Number | Participants Demographics | | |
|---|---|---|---|
| | Age (Years) | Autism severity | Verbal or non–verbal |
| N1 | 8 | Low | Verbal |
| N2 | 13 | Low | Verbal |
| N3 | 12 | Low | Verbal |
| N4 | 16 | Moderate | Partially |
| N5 | 10 | Low | Partially |

Table 1. Participant demographics

### 3.2 Emotional Engagement and Experiential Learning

#### 1. Children's Reactions

During the VR flight simulation, children with ASD consistently displayed positive emotional responses. Many expressed feelings of happiness, excitement, and enjoyment, indicating that the simulation was not only tolerable but also engaging. Some children expressed interest in repeating the experience, reinforcing the idea that the immersive environment felt playful and enjoyable:

*"It was like a game and entertained me."*
Participant N1

*"I was happy, and I liked the experiment."*
Participant N2

#### 2. Parent Observations of Child Emotions

Families provided valuable insights into the emotional states of their children throughout the simulation. Several parents reported that their children appeared excited, happy, and eager to participate:

*"My child was genuinely excited during the experiment."*
Family of N1

*"My child seemed happy with the experiment and expressed a desire to participate again."*
Family of N3

### 3.3 VR as a Tool for Experiential Learning

Another core theme that emerged was the role of VR in promoting experiential learning, a process where children gain knowledge through direct interaction and sensory experience [33]. The VR airplane setting allowed children to explore elements like seats, overhead compartments, and cabin structure, offering a tactile and immersive learning environment. This practical exposure supported the transformation of novel experiences into meaningful understanding.

One parent noted: *"The experience is very important. He interacted with the environment, exploring chairs and the bag shelf. Simulation is a great tool to gain experience for children."*
Family of N4

### 3.4 Interactive Engagement Through VR

The VR airplane simulation encouraged active exploration and interaction, allowing children with ASD to engage meaningfully with their surroundings. Participants interacted with elements such as seats, seatbelts, and baggage racks, fostering hands-on learning within a controlled environment. This interaction played a vital role in building familiarity and comfort with the travel setting.

*"He interacted with the environment, exploring chairs and the bag shelf."*
Family of N4

*"My child kept exploring and interacting with the environment."*
Family of N5

### 3.5 Supporting Travel Preparation

Families consistently reported that the VR simulation helped their children better understand and anticipate what to expect during real-life air travel. The immersive experience introduced the children to seating layouts, safety instructions, and general airplane etiquette-all of which helped reduce anxiety about unfamiliar experiences.

*"Simulation is a very important tool to prepare the autistic child for new experiences such as airplane travel."*
Family of N1

*"Now that he's had this exposure, it might be less annoying or scary."*
Family of N2

*"This experiment helps by giving exposure to the seats, the environment, and safety instructions."*
Family of N3



### 3.6 Realism and Near-Authentic Experience

A strong theme that emerged was the high level of realism in the simulation. Both children and parents highlighted how closely the environment mimicked a real airplane cabin. From seating arrangements to seatbelts and windows, the details contributed to a sense of authenticity that enhanced the learning experience.

*"The room looked exactly like an airplane cabin."*
Families of N4 and N5

*"Same seat, same seatbelt, same windows, and same bags shelf."*
Participant N1

*"It looked like a real plane cabin."*
Family of N3

### 3.7 Safe and Structured Learning Space

The simulation provided a quiet, structured, and sensory-friendly alternative to the typically overwhelming environment of real airplanes. This created a safe space where children could learn and practice essential behaviors without the pressure or unpredictability of actual travel.

*"I liked the simulation more than the real plane because the place is quieter and more organized."*
Family of N5

### 3.8 Recommendations for Enhancing VR Simulations

Feedback from families revealed several practical recommendations aimed at enhancing the effectiveness of the VR flight simulation experience. These suggestions focus on increasing the complexity and realism of the scenarios to better prepare children with ASD for the broader spectrum of real-life travel and milestone experiences.

Parents emphasized the need to include more nuanced and dynamic features in the simulation to replicate actual flight experiences. One parent suggested simulating key travel events such as:

#### 1. Takeoff and Landing with Sound Effects:

*"A more complex scenario with the plane taking off and landing, sound effects, a flight attendant helping him find his seat, and instructions on using seat belts would be very helpful."*
Family of N2

This highlights the importance of familiarizing children with auditory and procedural cues in air travel, which are often sources of anxiety.

#### 2. Simulate Challenging Travel Milestones

Another parent identified high-stress stages of travel, such as boarding, security checks, and waiting in line, as critical areas that should be included in the VR experience.

*"The most difficult parts for families are boarding, weighing, and waiting in line. These should be included in the simulation."*
Family of N3

Incorporating these transitional and often chaotic moments can help desensitize children to potential stressors and prepare them for real-world challenges.

#### 3. Expand Simulations Beyond Travel

Beyond air travel, families saw the potential of VR as a tool to prepare children for other milestone experiences. Suggestions included:

*"Creating more simulation scenarios, like going to the dentist or other important milestones, would be great."*
Family of N1

This insight broadens the application of VR beyond aviation, positioning it as a powerful tool for preparing autistic children for various anxiety-inducing or unfamiliar situations.

## 4. Discussion

This study demonstrates the significant promise of VR in supporting children diagnosed with autism as they prepare for unfamiliar and often overwhelming experiences, specifically, air travel. Through an immersive flight simulation, children engaged with their environment, expressed positive emotions, and practiced behaviors that are otherwise difficult to rehearse in real life. The results not only affirm VR's emotional and educational impact but also offer practical insights into how such interventions can be designed and scaled in broader therapeutic or educational contexts.

One of the most encouraging outcomes was the consistently positive emotional response observed in the children. They showed signs of curiosity, joy, and comfort while interacting with the simulated environment. This emotional resonance aligns with [31], who highlight the role of "presence" in VR as a driver of emotional involvement and learning. The immersive nature of the flight simulation appeared to enable a state of "flow," a psychological condition described by Csikszentmihalyi [32], in which individuals become deeply engaged in an activity that matches their abilities with an appropriate level of challenge. Such experiences not only make learning enjoyable but can also regulate anxiety and build emotional resilience.

Comparable findings in other neurodevelopmental populations, such as children with cerebral palsy, reinforce this outcome. Reid's research demonstrated that VR can significantly increase playfulness and concentration through flow states, echoing our participants' reactions [33]. In this study, the ability to interact safely and autonomously within the virtual environment allowed children with autism to build confidence and explore without the pressures typically associated with public or sensory-intensive settings.

In addition to emotional benefits, the VR flight simulation proved effective as a platform for experiential learning. Rooted in Kolb's learning theory, this approach emphasizes knowledge acquisition through direct experience [34], [35]. Within the VR setting, children actively practiced boarding behaviors, engaged with physical elements such as seatbelts and tray tables, and responded to structured cues within the cabin. This supports earlier findings by Kandalaft et al. [36], who demonstrated that VR-based training can enhance social and functional skills in individuals with autism. The strength of VR lies in its ability to offer a safe, repeatable, and controlled learning environment. Children can rehearse scenarios multiple times, receive feedback, and gradually build competence in settings that might otherwise be inaccessible. Furthermore, VR simulations allow for customization, making them adaptable to varying developmental needs and sensory profiles.

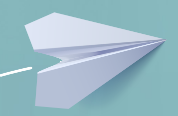
A defining feature of the flight simulation's success was its attention to realism. Participants and their families repeatedly noted how the environment mirrored a real aircraft cabin, complete with seats, seatbelts, windows, and baggage compartments. This level of fidelity is crucial, as research shows that skill generalization improves when simulated environments closely match real-world conditions [37], [38]. Moreover, the calm and structured nature of the VR environment offered a stark contrast to the chaotic and sensory-heavy experience of actual airports or flights. For children with autism, who are often highly sensitive to unpredictability, this made the simulation not only more accessible but also more effective in fostering familiarity without overwhelming them.

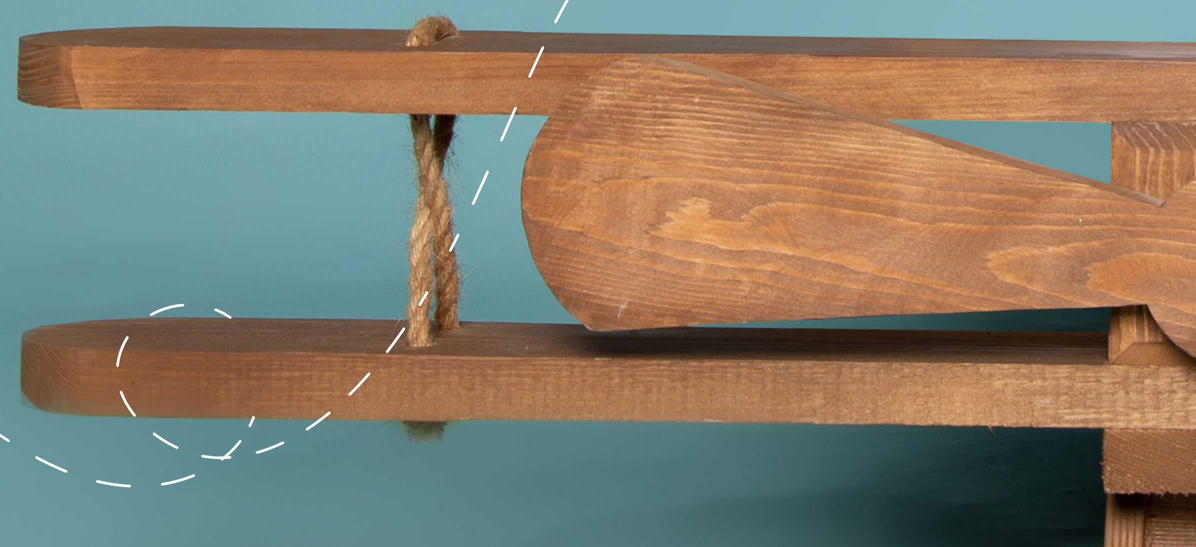


The findings of this study have meaningful implications for the use of VR technology beyond just air travel. By allowing children to familiarize themselves with new experiences in a low-stress, highly controlled environment, VR interventions can reduce anxiety, improve preparedness, and enhance overall quality of life for both children and their families. Simulations can be further extended to other real-world challenges -visiting the dentist, attending social events, or navigating public transport, making VR a versatile tool for daily life preparation. Additionally, the results suggest that emotional readiness, experiential learning, and environmental realism are not isolated components, but work together synergistically. This opens the door to multidisciplinary VR applications, combining behavioral therapy, occupational therapy, and special education practices into one integrated platform.

Despite its promising results, the study does carry some limitations. The small sample size restricts the generalizability of findings, and the reliance on parent-reported outcomes introduces the potential for subjective bias. Objective physiological data, such as heart rate or stress biomarkers, could provide more robust evidence of emotional impact in future studies. Moreover, while the immediate effects were positive, the study did not assess long-term outcomes or real-world transfer of skills post-simulation. It remains unclear how enduring the benefits are, or whether they hold up under the actual pressures of air travel. Future research should address these gaps through longitudinal designs and control comparisons.

Building on this initial success, future VR interventions should explore more complex and realistic scenarios, such as takeoff, landing, queuing, or interaction with flight crew, to better simulate the full travel experience. Expanding the use of VR into other domains of life (e.g., medical appointments, school transitions, or social gatherings) could offer even broader benefits. There is also potential in enhancing VR systems with adaptive sensory elements like soundscapes, tactile feedback, and real-time emotional tracking using AI or biometric sensors. These enhancements could not only deepen immersion but also provide practitioners with live feedback on how children are reacting during the simulation. Such data would be invaluable for tailoring interventions and supporting more personalized therapeutic strategies.





## 5. Conclusion

**This study highlights the promising potential of VR as an educational and preparatory tool for children with ASD, specifically through the novel use of a VR flight simulator. By immersing participants in a realistic travel environment, the research offered valuable insights into their emotional and behavioral responses. Four key themes emerged: emotional engagement, experiential learning, the realism of the simulation, and constructive feedback for future improvement. The study revealed that VR can evoke positive emotional reactions and provide a safe, enjoyable space for children with ASD to learn and explore. These findings support the idea that immersive experiences, such as VR flight simulations, can foster deep engagement, consistent with the principles of flow theory and enhance the learning process. Additionally, the active involvement of children during the simulation reflects the principles of Kolb's experiential learning model [34], emphasizing VR's effectiveness in creating hands-on, meaningful learning opportunities. This research makes a compelling case for integrating VR into educational strategies designed for children with ASD. Importantly, participants' suggestions to include more complex and varied scenarios point toward future directions for improving VR applications, potentially increasing the real-world applicability and generalization of skills learned in virtual environments.**



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# Moving Beyond Limits

## ALMOURAFEK's Trailblazing Innovation for the Visually Impaired

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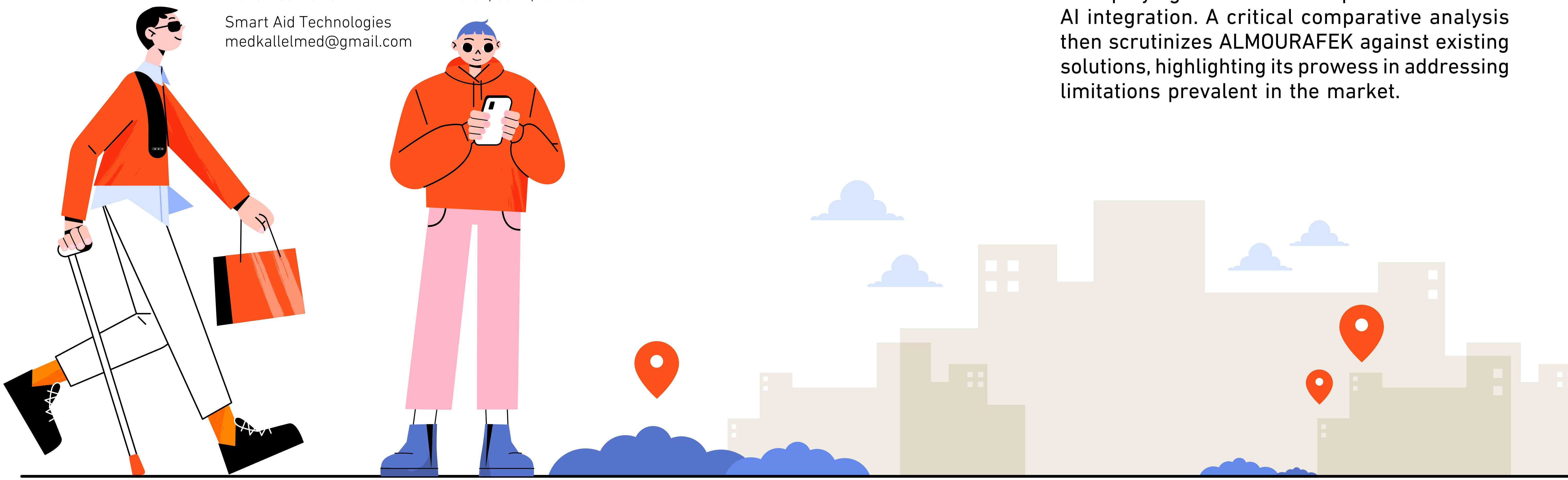



**Keywords**
Visual Impairment; Navigation Assistance; Wearable Device; Embedded AI Solution; Scene Interpretation.

**Abstract** - Recent advancements in technology have prompted innovative solutions in the field of navigation assistance for visually impaired individuals. Despite these strides, challenges persist in implementing autonomous navigation technologies due to accuracy, cost, and dependency on internet connectivity. This paper introduces 'ALMOURAFEK,' an ingenious smart, wearable device meticulously crafted with a fully embedded AI solution for indoor scene analysis and interpretation. It transforms images of indoor environments into actionable insights, formulating them into verbal messages directly transmitted by BT to the user in their preferred language and dialect. The paper details 'ALMOURAFEK's' software, hardware, and design intricacies, exemplifying the device's exceptional embedded AI integration. A critical comparative analysis then scrutinizes ALMOURAFEK against existing solutions, highlighting its prowess in addressing limitations prevalent in the market.

## 1. Introduction

In recent years, the field of navigation assistance for visually impaired individuals has witnessed the emergence of various technological solutions such as Lidar sensors, voice recognition systems, and image processing algorithms. However, implementing these technologies for autonomous navigation among visually impaired individuals poses notable challenges related to accuracy, cost, and ease of use. Moreover, the reliance of most existing systems on an Internet connection restricts their functionality in areas lacking connectivity.

This paper introduces 'ALMOURAFEK,' a pioneering innovation: a smart, wearable device designed for obstacle and stair detection and recognition. ALMOURAFEK stands out for its multilingual capabilities, user-friendly tool requiring no training, and notably, its capability to operate entirely offline, thereby enhancing performance and ensuring user privacy.

We start by providing a brief survey of the current technological landscape in navigation assistance for the visually impaired. Subsequently, a comprehensive depiction of 'ALMOURAFEK,' our innovative solution encompassing software, hardware, and design features, is presented. This is followed by a critical comparative analysis between ALMOURAFEK and existing solutions available in the market. Finally, the paper culminates by highlighting the pivotal role of ALMOURAFEK in revolutionizing navigation assistance technologies for the visually impaired.

## 2. State of the Art in Navigation Assistance Technologies for the Visually Impaired

According to the World Health Organization's 2021 statistics, approximately 253 million individuals worldwide are affected by visual impairment (VI), among whom 36 million are blind, and 217 million suffer from low vision. These statistics highlight the pressing need for robust and accessible assistive technologies to enhance the quality of life for visually impaired individuals.

### 2.1. Evolution of Assistive Solutions

Over the past decade, the development of assistive solutions dedicated to aiding visually impaired individuals in navigation across indoor and outdoor environments has surged significantly. Efforts have focused on bolstering user cognition during navigation and improving overall quality of life. Surveys, such as that conducted by [1, 2], have meticulously assessed wearable and portable assistive devices for the blind and visually impaired, shedding light on strengths and limitations.

### 2.2. Sensorial/Camera-Based Devices

Despite promising potential, sensorial and camera-based substitution devices have not seen widespread adoption within the visually impaired community. Challenges persist, notably in the inability to develop comprehensive cognitive maps of environments, hindering seamless navigation and integration of these technologies into daily life [3, 4]. Additionally, limitations in accuracy and precision within proposed architectures have posed hurdles [5].



### 2.3. Mobile Platforms and Cloud-Based Solutions

Recent years have witnessed a proliferation of research dedicated to sensorial substitution for human vision, often leveraging mobile platforms and cloud resources to offer a myriad of assistive applications. However, reliance on internet connectivity and limited testing in controlled laboratory environments have restrained their societal integration and usability [6].

### 2.4. Hybrid Technologies for Enhanced Navigation

To bridge the gap between current assistive technologies and human-level semantic content understanding, a proposition emerges: a hybridization of technologies, merging computer vision with voice recognition capabilities integrated into wearable devices. Such integration aims to offer a versatile, hands-free, and universally accepted assistive device within the visually impaired community [7, 8].

### 2.5. Wayfinding Technologies in Smart Cities

Inclusive design principles in smart cities emphasize the importance of accessible wayfinding technologies for individuals with disabilities. Leveraging indoor and outdoor navigation solutions, public spaces, including transport hubs, entertainment centers, and tourist attractions, are increasingly adapting to ensure inclusivity and accessibility [9, 10].

### 2.6. Challenges Faced by Wearable Assistive Devices

Wearable assistive devices have historically encountered multifaceted challenges, hindering their widespread adoption among visually impaired individuals. Complex operational procedures, high costs, and limitations in real-world effectiveness have posed substantial barriers to their integration into daily life [1, 12]. Moreover, socio-psychological factors, including hesitance towards embracing new technologies, have impeded user acceptance.

A prominent challenge prevalent in existing solutions is their dependency on internet connectivity. This reliance restricts user liberty and privacy, as constant connectivity may not always be feasible or preferred when navigating various environments. This constraint has not only posed practical limitations but also raised concerns about the privacy and autonomy of users, potentially impeding the seamless adoption of such technologies into everyday life.

## 3. ALMOURAFEK: Wearable Device with fully embedded AI solutions for the Visually Impaired

ALMOURAFEK stands as a groundbreaking solution designed to address the challenges faced by over 253 million visually impaired individuals worldwide. While the majority still rely on white canes, they remain susceptible to collisions, stair accidents, and disorientation. Meanwhile, a minority with access to technology, notably SmartPhones, encounter usability complexities, requiring both mastery and internet connectivity.

To bridge these gaps, ALMOURAFEK provides a comprehensive, secure solution. Our system utilizes a TOF camera for real-time environmental capture, integrating tailored artificial intelligence to detect various obstacles. Crucial information is then relayed to users in their preferred language and dialect. ALMOURAFEK's key advantage lies in its operation without internet, ensuring user safety and independence, even in connectivity-deprived zones. Furthermore, its ease of use requires no mastery: simply activate and listen.

### 3.1. ALMOURAFEK: A Pioneering Intelligent Wearable Device

"ALMOURAFEK" is a wearable smart device equipped with specialized artificial intelligence to analyze and interpret a visually impaired individual's surrounding scene. It processes vital information and transmits it verbally to the user via a BT earpiece. ALMOURAFEK excels in detecting and recognizing components in both indoor and outdoor scenes. With multilingual capabilities and user-friendly operation requiring no training, it offers the option to function without internet connection, ensuring improved system performance, functionality anywhere, and user privacy.

The device is equipped with a TOF camera, a Bluetooth earpiece and a rechargeable battery (refer to Figure 1). ALMOURAFEK boasts convenient weight and dimensions.

exceptional embedded AI integration. A critical comparative analysis then scrutinizes ALMOURAFEK against existing solutions, highlighting its prowess in addressing limitations prevalent in the market.

1. Power button
2. Camera
3. Menu button
4. Up button
5. Down button
6. Power connector USB-C
7. HDMI connector
8. External battery
9. Bluetooth earphones

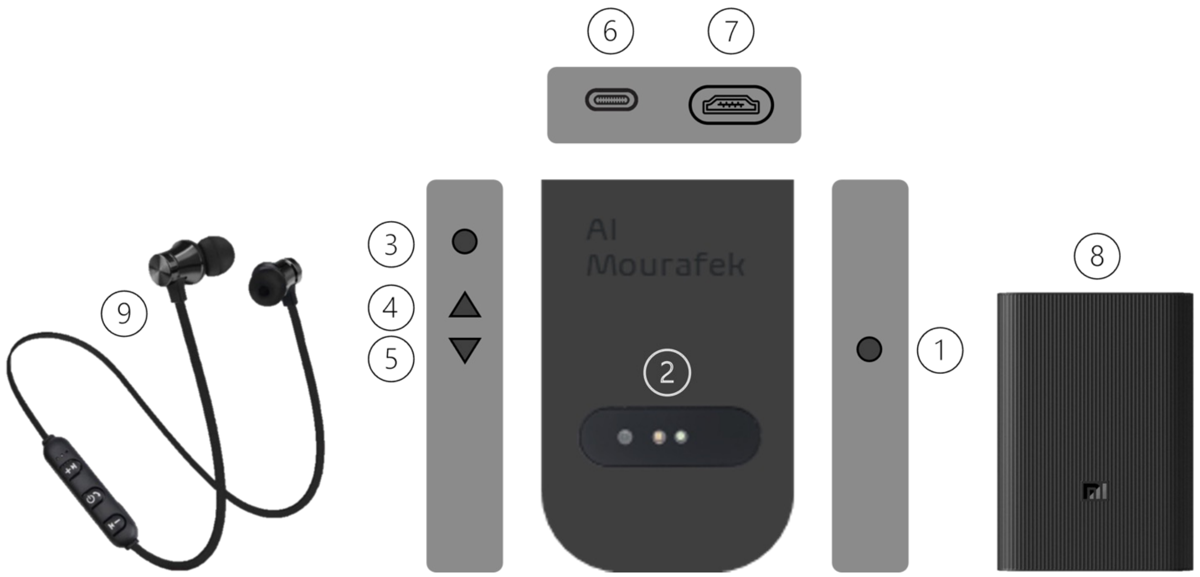


Figure 1. ALMOURAFEK basic device.



### 3.2. Accessories for Enhanced User Experience

Almourafek is designed to offer a simple, intuitive, and completely hands-free user experience. The device is worn discreetly as a pendant or can be attached to accessories like a scarf (refer to Figure 2). It requires no physical manipulation during use, allowing the user to fully focus on their movements. The user interface is activated by a simple button, and voice feedback is transmitted using a Bluetooth earpiece.

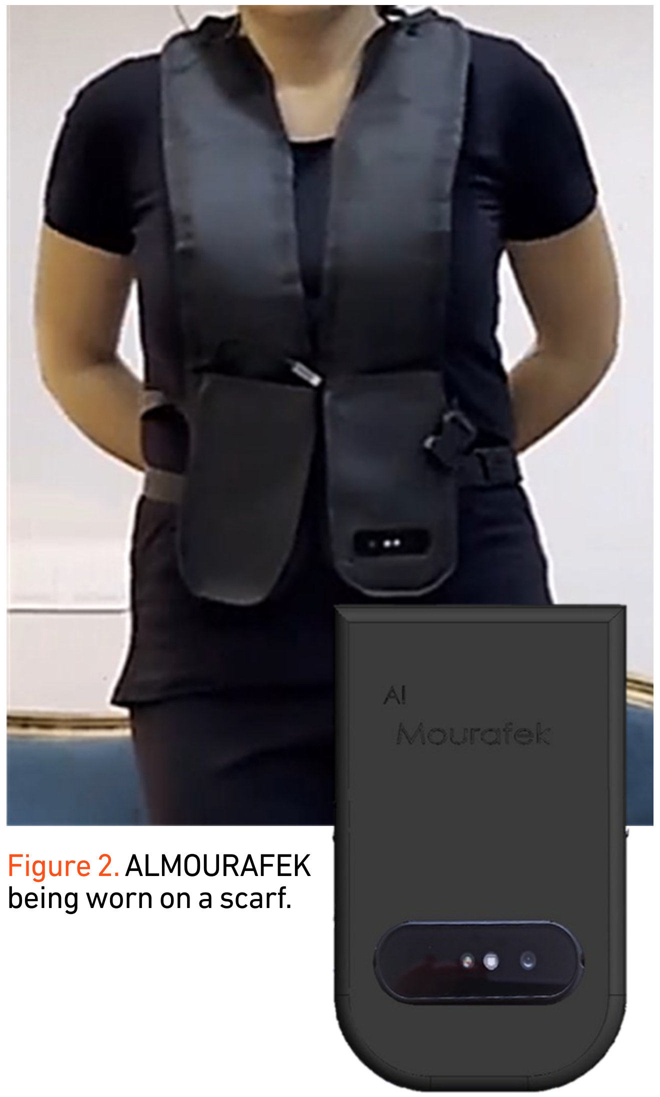


Figure 2. ALMOURAFEK being worn on a scarf.

### 3.3. A User-Centric Development Approach

Our device heavily relies on our innovative algorithms that have proven to be extremely revolutionary through multiple papers we've authored [13-19]. Our algorithms play a huge part in offering us a significant competitive advantage as we're able to efficiently and rapidly detect all kinds of obstacles, especially up and down stairs and suspended obstacles that often represent a huge risk and problem even with the currently available solutions.

The innovative approach adopted relies on the use of a Time-of-Flight (TOF) camera to capture real-time surroundings for VI individuals. Our system leverages advanced image processing and artificial intelligence (AI) techniques to analyze and interpret this visual and depth data.

The entire surrounding scene is acquired using the TOF camera, with a field of view of 86°*68° and a range of 6 meters, providing two types of images: an infrared image (IR) and a depth image (Depth). Then, computer vision algorithms and deep learning come into play to segment the scene and identify its different elements respectively, such as obstacles, open pathways, objects, and others. Indeed, each image type undergoes specific parallel processing as shown in Figure 3.

To the best of our knowledge, ALMOURAFEK stands as a unique tool capable of conducting real-time offline scene analysis, providing essential functionalities for the visually impaired, including obstacle detection and scene description. It not only ensures their safety but also establishes itself as a genuine companion, transcending mere obstacle detection to offer comprehensive assistance.

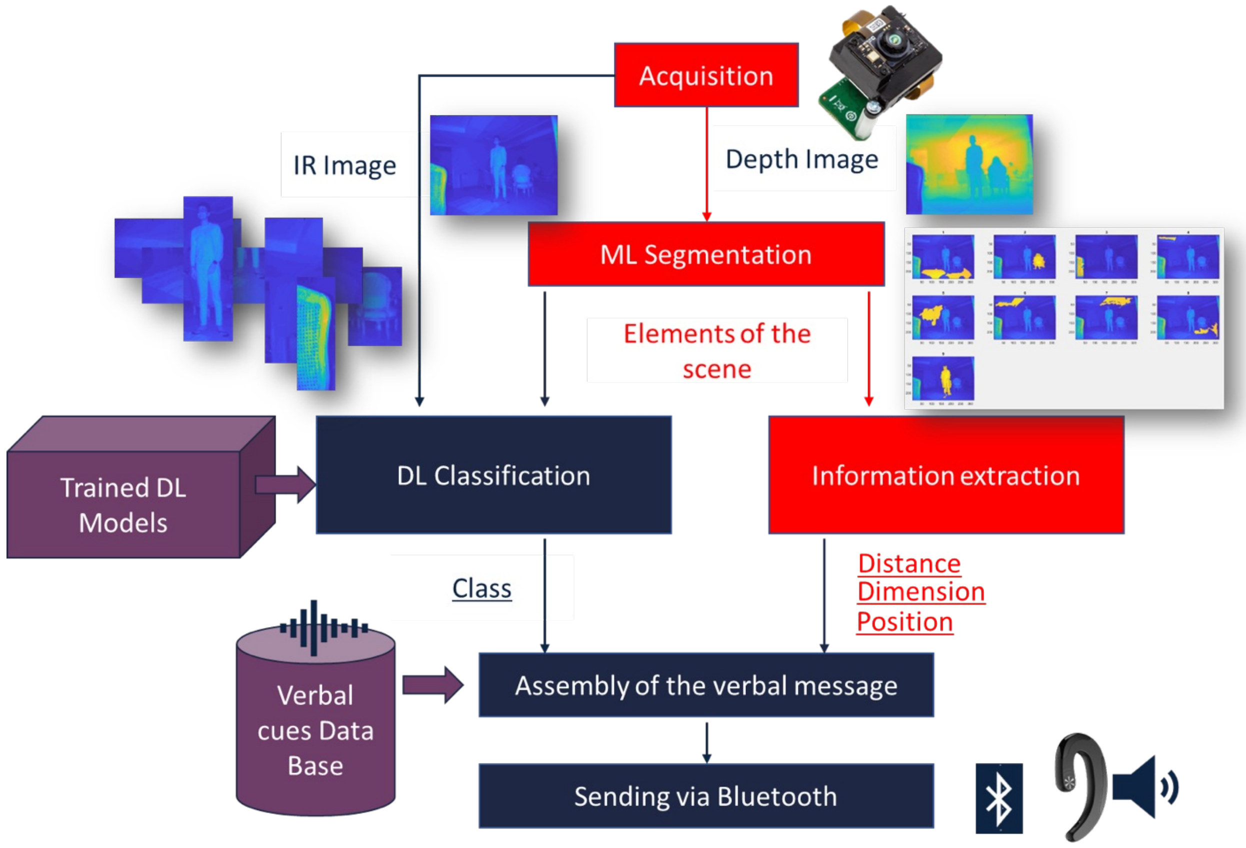


Figure 3. Flowchart of our Computer Vision Approach for Real-Time Scene Understanding and Interpretation.

Finally, the development and design of our product stemmed from a thorough study of the needs of visually impaired individuals, ensuring ALMOURAFEK stands as the perfect companion for the visually impaired.



## 4. Conclusion

Underpinning the challenges in existing navigation aids for the visually impaired, this study introduced ALMOURAFEK, a paradigm-shifting wearable device embedded with advanced artificial intelligence and Time-of-Flight (TOF) camera technology. ALMOURAFEK's operational independence from internet connectivity ensures enhanced safety and privacy while offering real-time scene analysis and multilingual assistance.

This innovative device, designed through a user-centric approach, not only addresses the limitations of current aids but also showcases adaptability by being worn on scarves or integrated into white cane extensions.

By amalgamating cutting-edge science with user-oriented design, ALMOURAFEK embodies the future of assistive technologies, promising greater independence, societal inclusion, and an elevated quality of life for the visually impaired on a global scale. Its scientific advancements signify a transformative shift in the domain of navigation aids, heralding an era of empowerment and accessibility for millions.

## Acknowledgments

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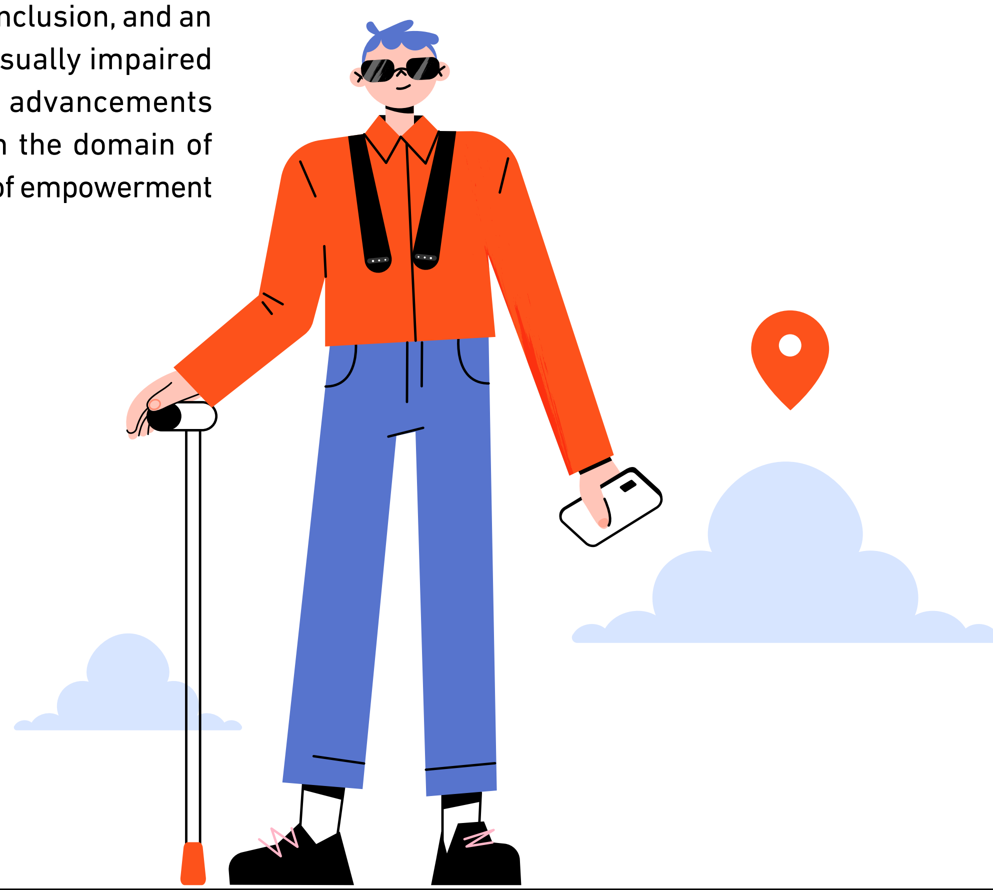

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# Too Many Tabs Open? Using Everyday Computer Data to Support Focus for adults with ADHD

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**Abstract** - Adults with ADHD often struggle to maintain focus in digital environments, where multiple tabs and applications compete for attention. Although attention can be measured in clinical settings, there is a need for practical tools that operate in everyday contexts. This proof-of-concept study investigates whether simple patterns of computer use—such as tab switching frequency, idle time, and relevance of activity to the intended task—can be used to estimate attention in real time. A machine learning model trained on these features achieved a cross-validated $R^2$ of 0.77 within a small, simulated dataset—suggesting potential for this approach in predicting moment-to-moment attention. This approach has potential to inform more adaptive, accessible tools to support focus and self-regulation for adults with ADHD. As a preliminary proof-of-concept, these findings require validation in the real-world, ecologically valid settings with larger and more diverse samples.

**Keywords** - ADHD; Attention Estimation; Passive Monitoring; Assistive Technology; Human-Computer Interaction; Machine Learning; Neurodivergence.

## 1. Introduction

For adults with Attention-Deficit/ Hyperactivity Disorder (ADHD), everyday digital environments are full of potential distractions—constant notifications, endless browser tabs, and easy access to unrelated content [1], [2], [3]. Sustaining attention in this context is difficult, and the effects on study, work, and wellbeing can be substantial.

Despite the importance of attention in daily functioning, current tools for measuring it fall short, particularly outside of clinical or laboratory settings. Eye-tracking and EEG can provide precise, real-time data [4], but are expensive, intrusive, and impractical for long-term use [5]. In addition, eye tracking approaches can only identify attention on one device. Given how frequently internet users switch devices (e.g. looking something up on their phone while watching a lecture on their computer), an attention measurement system must consider what the user is interacting with across all their devices.

Self-report scales are more scalable but rely on memory and offer only coarse snapshots of experience [6]. It is akin to relying on occasional oral glucose tolerance tests to manage diabetes—accurate in determining a baseline but unhelpful for tracking everyday fluctuations. As a result, researchers, clinicians, and neurodivergent individuals often lack practical tools to monitor how attention changes throughout the day or in response to interventions. Table 1 summarizes the strengths and limitations of common attention measurement methods, highlighting how our approach addresses key gaps in ecological validity and goal alignment.



| Method | Real time? | Ecologically valid? | No additional hardware needed? | Minimally intrusive? | Scalable? |
|---|---|---|---|---|---|
| EEG | ✓ | ✗ | ✗ | ✗ | ✗ |
| Eye tracking | ✓ | ✗ (can't detect whether the app usage aligns with user's goals) | ✗ | ✗ | ✗ |
| Self-report surveys | ✗ | ✗ | ✓ | ✓ | ✓ |
| App usage analysis | ✓ | ✗ (can't detect whether the app usage aligns with user's goals) | ✓ | ✓ | ✓ |
| Focus Bear computer usage + AI analysis | ✓ | ✓ | ✓ | ✓ | ✓ |

**Table 1.** Comparison of attention measurement methods

This study explores a more accessible and ecologically valid approach. By analyzing natural computer usage data, such as how often a person switches tabs, how long they are inactive, and whether their activity aligns with a declared focus goal, we aim to estimate attention in real time. Our goal is to enable continuous, high-resolution measurement of attention without the need for specialized hardware.

This data could allow individuals to monitor their attention patterns across days or weeks, helping them see whether strategies like medication, coaching, or behavioral interventions are having an impact. It could also help researchers and clinicians better understand the daily lived experience of ADHD, opening the door to more personalized and responsive care.

In this proof-of-concept study, we used data collected through Focus Bear [7] an assistive technology app designed to support attention and routine-building for neurodivergent users. The app passively tracks computer activity (e.g. tab switching, idle time, and focus goal alignment) to encourage more intentional work sessions. We trained a machine learning model to estimate moment-to-moment attention using these metrics, validated against labelled recordings of participants enacting real-world focus and distraction scenarios. This paper presents the methodology, results, and implications for both assistive technology and clinical research. As a proof-of-concept study with simulated data, the findings should be interpreted cautiously. While the modelling pipeline shows promise, its generalizability and real-world utility remain to be tested in ecologically valid environments with diverse participants.

## 2. Methodology

### 2.1. Study Design

This was a proof-of-concept study designed to explore whether real-time attention could be estimated using everyday computer usage data. The aim was to validate the feasibility of a lightweight, accessible system for tracking attention without the need for specialized hardware.

### 2.2. Participants

Six postgraduate data science students from RMIT University participated as part of a supervised capstone project. All were members of the research team and are co-authors on this study. Participants were aware of the study goals and intentionally enacted a range of attentional states, introducing a potential bias in behavior and labelling. While not representative of a clinical population, this sample was appropriate for validating system feasibility and refining the data labelling and modelling pipeline.

### 2.3. Procedure

Each participant completed a 20–30-minute session in a controlled lab environment. Instead of working naturally, they were asked to enact a range of attentional scenarios designed to mimic real-life fluctuations in focus. These included periods of concentrated work on a specific goal (e.g. "revise assignment" or "write lab report"), as well as intentional distractions such as checking their phone while a document was open, taking handwritten notes away from the screen, browsing unrelated websites (e.g. reading the news instead of studying), and physically stepping away from the computer to simulate breaks (e.g. going to the toilet). This approach enabled the creation of a diverse dataset with clearly defined high- and low-attention states for model training.

Before each session, participants declared a focus goal in the Focus Bear app (e.g. "revise assignment" or "write report"). This helped contextualize whether their on-screen activity was aligned with their intended task.

During the session, we captured:

- Screen recordings using OBS Studio.
- Workstation recordings from a side-mounted webcam.
- Computer usage metrics from the Focus Bear app, including:
  - Number of browser tabs open
  - Average tab switching speed
  - Idle time (in seconds)

Task relevance score – estimated using GPT-4.1, which was prompted to assess whether the active website (based on URL, tab title, and meta description) aligned with the participant's declared focus goal.

#### Attention Scoring

Every three seconds, a frame from the screen and workstation recordings was extracted. These were labelled using GPT-4.1 Vision, which rated:

- **Screen attention** – based on whether the on-screen activity matched the declared focus goal
- **Workstation attention** – based on posture, presence, and signs of physical distraction (e.g. phone use)

Each score ranged from 0 (not attentive) to 1 (fully attentive).

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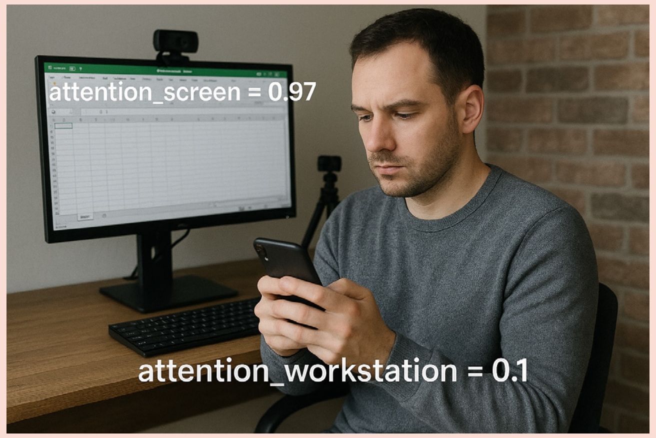


**Figure 1.** Screen-focused distraction with low workstation engagement.

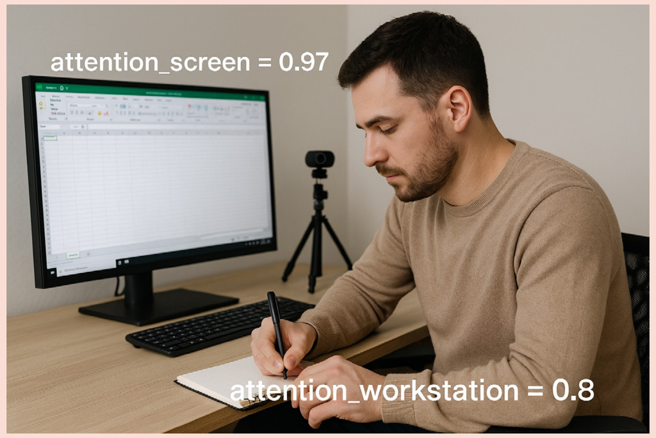


**Figure 2.** High attention to both screen and workstation during active task engagement.

The overall attention score was calculated as:

**attention = screen_score × workstation_score**

A random 10% of labelled frames were manually reviewed to ensure plausibility and internal consistency. While we did not formally assess inter-rater reliability, this manual check suggested a high face-validity of the GPT-based labelling approach. Given the exploratory nature of this study and the resource constraints, this method was deemed sufficient for early-stage prototyping.

All video recordings were deleted after frame extraction to preserve privacy.

#### Dataset and Model Training

The final dataset contained 1,340 three-second snapshots, each with:

- Input features: tab count, tab switching speed, idle time, and task relevance
- Target: an attention score derived from video-based labelling

Data were normalized and fed into a series of regression models, evaluated using 10-fold cross-validation. Models included:

- Linear Regression
- Random Forest
- Gradient Boosting
- Extra Trees Regressor

## 3. Results

The dataset contained 1,340 labelled snapshots across all participants. Each snapshot corresponded to a 3-second interval, paired with app-based metrics and an attention score derived from video frame analysis.

We evaluated four regression models using 10-fold cross-validation. The **Extra Trees Regressor** consistently outperformed the others, achieving a mean **$R^2$ of 0.77,** indicating a strong relationship between usage metrics and attention scores even in a small, synthetic sample.

| Model | Best Parameters | $R^2$ Score | MAE | RMSE |
|---|---|---|---|---|
| Extra Trees | max_depth=20, min_samples_split=5, n_estimators=100 | 0.7997 | 0.0597 | 0.1236 |
| Random Forest | max_depth=10, min_samples_split=5, n_estimators=200 | 0.7826 | 0.0644 | 0.1281 |
| Gradient Boosting | learning_rate=0.1, max_depth=5, n_estimators=100 | 0.7769 | 0.0644 | 0.1293 |
| Decision Tree | max_depth=10, min_samples_split=2 | 0.7380 | 0.0634 | 0.1402 |
| SVR | C=10, gamma='scale' | 0.5478 | 0.1288 | 0.1857 |
| Polynomial Regression | poly_features__degree = 2 | 0.4850 | 0.1521 | 0.1985 |
| Linear Regression | — | 0.1809 | 0.2156 | 0.2504 |

**Table 2.** Performance Comparison of Regression Models for Predicting Attention Metrics

Among the input features, the most informative were:

- **Focus alignment score** — higher semantic relevance to the declared goal strongly predicted higher attention.
- **Idle time** — prolonged inactivity correlated with reduced attentional engagement.
- **Average tab duration** — rapid tab switching often indicates reduced focus.
- **Tab count** — a higher number of open tabs had a weaker but still negative association with attention.

A sample of GPT-labelled frames (10%) was manually reviewed and showed high agreement with human interpretation, supporting the validity of the labelling approach.

## 4. Discussion

### 4.1. Summary of Findings

This study explored whether everyday computer usage data could be used to estimate attention in real time. The results show that even with a small, simulated dataset, machine learning models—particularly tree-based methods—can reliably predict attention levels using non-intrusive, passively collected features. The high $R^2$ value (0.77) indicates strong potential for this approach, especially considering its low cost and minimal user burden.

### 4.2. Model performance

Tree-based ensemble models (Extra Trees, Random Forest, Gradient Boosting) substantially outperformed linear and



kernel-based models. This suggests that attention, as inferred from passive usage data, involves non-linear interactions and hierarchical feature dependencies. For instance, tab switching may only signal distraction when focus alignment is also low — a relationship linear models struggled to capture.

The best-performing model, Extra Trees Regressor, achieved the highest $R^2$ and lowest error rates, likely due to its ability to handle collinearity, complex feature interactions, and noisy labels. Interestingly, it outperformed XGBoost despite both being ensemble methods and despite careful hyperparameter tuning for each. We suspect this is due to Extra Trees' robustness to label noise and its greater feature randomness, which helps prevent overfitting in smaller, noisier datasets. In contrast, XGBoost's sequential boosting structure may have been more sensitive to inconsistencies in the AI-derived attention scores.

SVR and Polynomial Regression underperformed due to their limited capacity to model non-linear relationships and tendency to overfit or underfit small, high-variance samples.

These outcomes are likely influenced by the modest dataset size (~1,300 samples) and may change with larger, more diverse training data. In future work, we expect boosting methods to improve in relative performance as the signal-to-noise ratio increases and residual errors become more informative.

### 4.3. Implications for ADHD and Accessibility

Adults with ADHD often struggle with attention regulation in digital environments, and existing measurement tools (e.g., clinical interviews, self-report, lab tests) are often impractical for day-to-day use. Our system offers a more inclusive, ecological alternative: a way to monitor focus using data most users already generate while working.

From an accessibility perspective, this approach aligns with the principles of universal design. It requires no specialized equipment or user intervention, making it well-suited for neurodivergent users who may find other attention-tracking tools intrusive, fatiguing, or unreliable.

This kind of passive, high-resolution attention tracking could eventually be used to:

- Evaluate the day-to-day effectiveness of ADHD interventions
- Identify optimal working periods based on chronotype and cognitive load
- Detect attention decline due to fatigue, illness, or environmental stressors
- Provide real-time feedback to help users manage distraction

#### 4.4. Limitations

As proof of concept, this study was limited in several important ways:

- All participants were members of the research team simulating attentional states
- Sessions were short (~25 minutes) and not representative of real-world focus sessions
- No participants with diagnosed ADHD were involved at this stage
- Attention labels were derived from GPT-4.1 classification, which, while efficient, may introduce occasional misclassifications
- The attentional metrics only included data from Mac computers. Future versions should work on mobile phones as well to holistically capture device usage.

#### 4.5. Next Steps: Ecological Validation in a Clinical Sample

The next phase of this research will involve ecological validation with a broader participant group, including adults with and without ADHD. This study will:

- Recruit **N=100 university students** aged 18–30
- Use **ADHD screening tools (ASRS)** to compare attention profiles
- Ask participants to use the Focus Bear app for **4 weeks,** during which usage metrics and model-predicted attention scores will be passively collected across their computer and phone
- Collect covariates such as sleep hours, medication use, study load, and tech literacy
- Examine how estimated attention fluctuates day to day, and whether average attention scores or variability differ between ADHD and neurotypical groups

This larger study will allow us to test generalizability, assess sensitivity to intervention effects (e.g. medication use), and evaluate how usable and acceptable the tool is for end users.



## 5.Conclusion

This proof-of-concept study demonstrates that real-time attention estimation is possible using passive computer usage data—without relying on invasive tools or self-report. By modelling features such as tab behavior, idle time, and task relevance, we achieved strong predictive performance in detecting shifts in attentional engagement.

For adults with ADHD, this represents a meaningful step toward more accessible, personalized tools for monitoring focus and supporting productivity. The approach aligns with inclusive design principles, offering a way to adapt to users' natural workflows rather than requiring behavior change.

Building on this foundation, the next phase will involve validating the model in a larger, ecologically valid study with university students, including those with ADHD. This will allow us to assess generalizability, track day-to-day fluctuations in focus, and explore whether this technology can meaningfully inform intervention and support strategies.

In doing so, we hope to contribute a scalable, neurodivergent-friendly alternative to traditional attention assessment—one that works not just in labs, but in life.

#### Conflict of Interest

Jeremy Nagel is the founder of Focus Bear; the software tool used in this study. All other authors declare no competing interests.

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# SafeDrive4Deaf
## A Mixed-Methods Study on Emergency Sound Awareness and Assistive Technology Needs Among Deaf and Hard-of-Hearing Drivers

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**Abstract**- Deaf and hard-of-hearing drivers often face critical challenges in perceiving emergency vehicle sirens and other important auditory cues while on the road, posing risks to both personal and public safety. This study explores these challenges and assesses the potential impact of the SafeDrive4Deaf assistive technology device, designed to enhance situational awareness through visual and directional alerts. Using a mixed-methods approach, data were collected from 25 deaf and hard-of-hearing drivers between the ages of 25 and 61, including 15 participants from Tunisia and 10 from Germany. Participants completed structured surveys and semi-structured interviews covering demographics, driving experience, comfort with technology, and awareness of emergency sounds. All participants reported difficulties in detecting emergency vehicles, regardless of their driving experience, which ranged from 5 to 40 years—and 100% expressed a need for enhanced alert systems. While 52% of drivers felt very comfortable with technology, 40% indicated discomfort, highlighting the need for inclusive and user-friendly design. The findings underscore the necessity of assistive driving solutions like SafeDrive4Deaf, which address both safety and accessibility through a community-informed approach. The results support continued development and pilot testing to validate the device's effectiveness in real-world driving scenarios.

**Keywords -** deaf drivers; emergency vehicle detection; assistive technology; road safety; digital accessibility; inclusive design.

## 1. Introduction

Road safety remains a critical concern worldwide, with challenges faced by drivers with sensory impairments (Chemnad & Othman, 2024). Deaf and hard-of-hearing individuals represent a significant portion of the driving population, yet their unique challenges and needs in automotive safety have received limited research attention. The ability to detect emergency vehicles, respond to auditory warning signals, and navigate complex traffic situations poses distinct challenges for this community (Lopez et al., 2025).

The development of assistive technologies for automotive applications has accelerated in recent years, driven by advances in sensor technology, artificial intelligence, and human-computer interaction. However, many existing solutions focus primarily on general driver assistance rather than addressing the specific needs of deaf and hard-of-hearing drivers. This gap in targeted assistive technology development motivated the creation of SafeDrive4Deaf, a specialized alert system designed to enhance road safety for deaf drivers (Beha, 2022).

This study aims to comprehensively analyze the challenges faced by deaf and hard-of-hearing drivers, evaluate their current technology usage patterns, and assess the potential impact and design requirements for the SafeDrive4Deaf assistive technology device supported by Mada Innovation Program (Al Thani et al., 2019). Through a mixed-methods approach combining quantitative surveys and qualitative interviews, we seek to provide evidence-based recommendations for improving road safety and accessibility for this underserved population.

## 2. Background and Literature Review

### 2.1. Challenges Faced by Deaf Drivers

Deaf and hard-of-hearing drivers encounter several unique challenges that differentiate their driving experience from hearing drivers:

**Sensory Awareness Limitations**

Deaf drivers depend extensively on visual inputs for situational awareness, often missing critical auditory cues such as vehicle horns, emergency sirens, and environmental sounds indicating potential hazards or urgent situations requiring immediate reaction. This heightened visual dependency can contribute to cognitive overload, particularly in complex traffic scenarios, potentially increasing response times and accident risks (Engelman, 2012). Public safety policy can address these limitations by mandating infrastructure adaptations such as visual alerts integrated with siren systems, enhancing situational awareness through synchronized siren-light signals at intersections and high-risk areas.

**Communication Barriers**

Interactions involving other drivers, pedestrians, and law enforcement personnel can present significant communication challenges, especially in urgent or emergency scenarios requiring quick verbal communication. Misunderstandings arising from these communication gaps can escalate routine encounters into hazardous incidents (Miranda et al., 2022). Policies encouraging standardized non-verbal communication protocols and training law enforcement on effective interaction techniques with deaf drivers could significantly reduce these risks.



**Emergency Vehicle Detection**

A critical challenge is detecting emergency vehicles, as deaf drivers cannot rely on traditional auditory signals like sirens. Delayed detection and subsequent response can interfere with emergency operations, posing significant risks to public safety (Choudhury & Nandi, 2023). Infrastructure adaptations, such as integrating visual alert systems like flashing lights synchronized with sirens at traffic intersections or embedding tactile feedback systems within vehicles to alert drivers of nearby emergency vehicles, could substantially mitigate these challenges. Policies advocating for mandatory integration of visual and tactile emergency alert systems in urban traffic infrastructures can enhance the efficacy of emergency response efforts and promote safer driving environments for deaf and hard-of-hearing individuals.

### 2.2. Current Assistive Technologies

The automotive industry has introduced significant advancements, including automatic emergency braking, blind spot detection, lane departure warnings, and adaptive cruise control systems. However, the reliance of many such technologies on auditory alerts diminishes their utility for deaf drivers. This gap underscores the urgent need for inclusive design practices emphasizing visual and tactile feedback integration. Public safety regulations can foster innovation by incentivizing manufacturers to develop and adopt multimodal feedback systems, ensuring technology equally benefits deaf and hearing drivers alike, thereby promoting comprehensive road safety.

## 3. Methodology

### 3.1. Study Design

This study employed a mixed-methods approach combining quantitative surveys and qualitative interviews to capture both breadth and depth of understanding regarding the driving experiences of deaf and hard-of-hearing individuals. The research design was specifically tailored to address the unique communication needs and preferences of the target population.

### 3.2. Participants

The study sample consisted of 25 deaf and hard-of-hearing drivers, aged between 25 and 61 years, with a median age of 41. Participants were drawn from two countries—Tunisia (n=15, 60%) and Germany (n=10, 40%)—and all met the inclusion criteria of self-identifying as deaf or hard-of-hearing, having regular driving experience, and holding a valid driving license. Notably, 100% of participants confirmed their active driving license status.

### 3.3. Structured Surveys for Data Collection Method

Structured questionnaires were administered to all participants, covering a range of domains including demographic details (age, nationality, country of residence), driving license status and years of experience, preferred driving environments and frequency of driving, comfort level with technology, and current use of assistive devices. The survey also explored participants' experiences with emergency sound awareness and the coping strategies they employ, as well as specific driving challenges and safety concerns. Additionally, participants were asked to provide feedback on the concept of the proposed SafeDrive4Deaf device. To enrich the quantitative data, follow-up semi-structured interviews were conducted with selected participants. These interviews offered deeper insights into individual survey responses, allowing participants to elaborate on their personal driving experiences and provide more detailed input on their technology needs and preferences.

### 3.4. Data Analysis

A comprehensive analytical approach was employed to interpret the data collected through surveys and interviews. Quantitative analysis involved the use of descriptive statistics to summarize demographic information, technology comfort levels, and driving patterns. Qualitative data, derived from open-ended survey responses and interview transcripts, were analyzed thematically using inductive coding to identify recurring issues, preferences, and insights. Feedback was systematically categorized into key themes, including driving challenges, levels of comfort with technology, and desired features for assistive devices. A cross-analysis was conducted to integrate quantitative trends with qualitative narratives, enabling a holistic understanding of participant needs and experiences. Finally, community validation was incorporated through participant feedback loops, ensuring that the emerging insights were accurate and directly informed the iterative design of the SafeDrive4Deaf device.

## 4. Results

### 4.1. Participants Demographics

#### Age Distribution

The study engaged a diverse group of 25 deaf participants, offering a broad range of insights into the driving experiences of the deaf and hard-of-hearing community. Participants aged 25 to 61 provided a cross-generational perspective on driving as deaf individuals.

The median age of study participants is 41. This indicates that half of the participants are younger than 41. In contrast, the other half are older, providing a balanced cross-section of age-related driving experiences within the deaf and hard-of-hearing community. The study engaged a diverse group of 25 deaf participants, offering a broad range of insights into the driving experiences of the deaf and hard-of-hearing community.

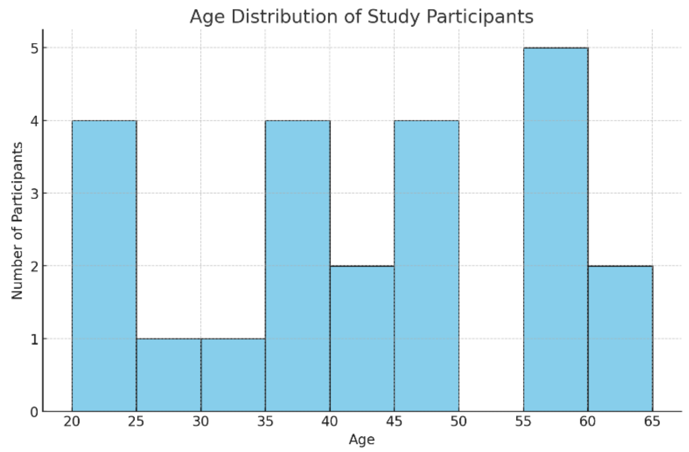


**Figure 1.** Age Distribution

#### Country of Residence

The study included 15 participants from Tunisia and 10 from Germany, offering a balanced representation from two distinct geographic and cultural contexts. This distribution provided diverse insights into the driving experiences, challenges, and assistive technology needs of the deaf and hard-of-hearing communities in both regions, enriching the study's findings through cross-cultural perspectives.

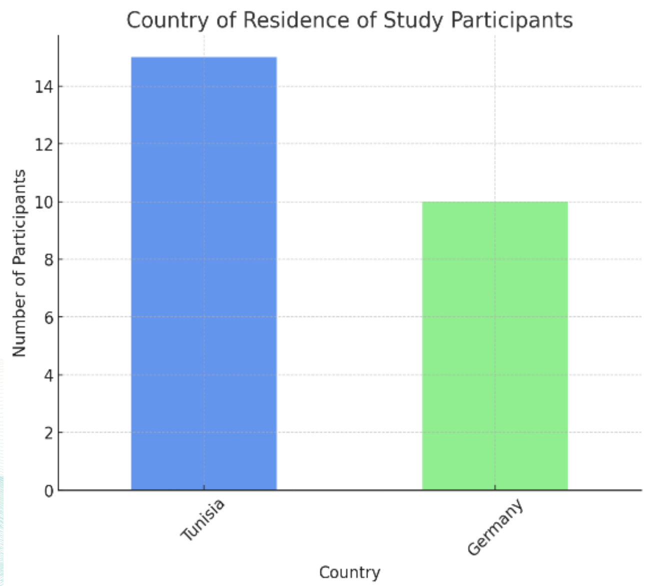


**Figure 2.** Country of Residence



#### Driving Environment

Out of the 25 participants, 19 reported primarily driving in urban environments, while 6 were based in rural areas. The predominance of urban drivers highlights context-specific challenges such as navigating heavy traffic and encountering emergency vehicles more frequently—factors that underscore the need for enhanced situational awareness tools. All participants held valid driving licenses, confirming their active engagement in regular driving activities.

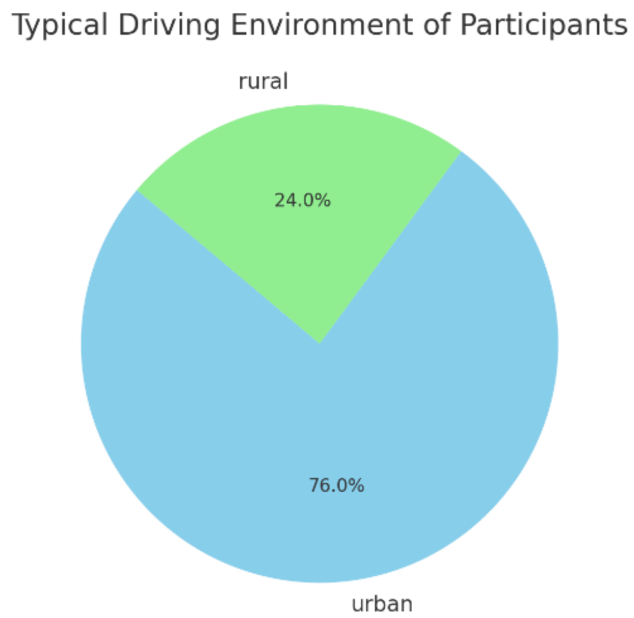


**Figure 3.** Typical Driving Environment of Participants

#### Technology Comfort Level

Participants expressed varying levels of comfort with new technology: 13 reported being very comfortable, 10 were not comfortable, and 2 felt somewhat comfortable. This range highlights the importance of ensuring that the SafeDrive4Deaf device is designed to be highly user-friendly and accessible, accommodating users with different levels of technological familiarity and confidence.

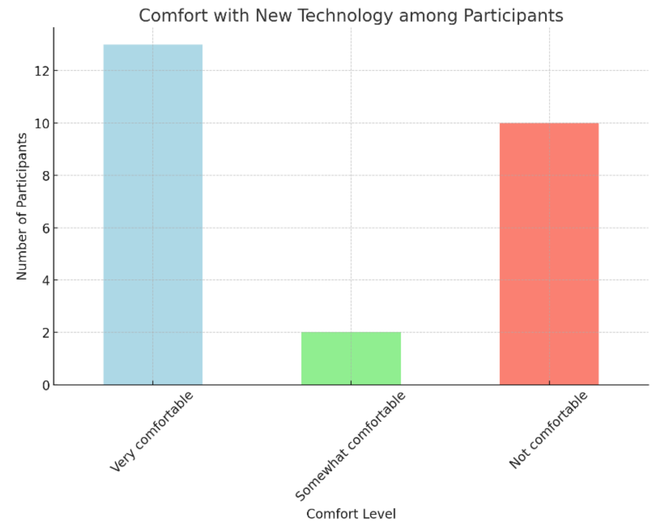


**Figure 4.** Technology Comfort Level

### Driving Frequency

Driving frequency among participants varied widely, with 8 individuals reporting daily driving, another 8 driving several times a week, 7 driving less frequently, and 2 driving on a weekly basis. This diversity in driving habits highlights the need for the SafeDrive4Deaf device to be adaptable and effective across different usage patterns, ensuring it meets the needs of both frequent and occasional drivers within the deaf and hard-of-hearing community.

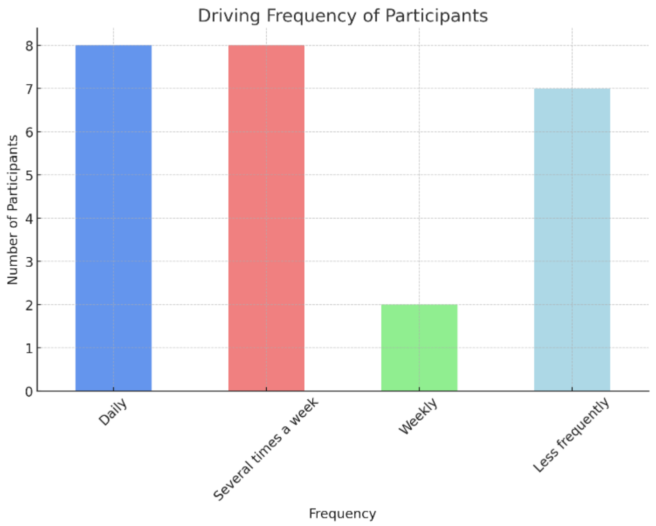


**Figure 5.** Driving Frequency

### Years of Driving Experience

Participants in the study had a wide range of driving experience, spanning from 5 to 40 years, reflecting a diverse group with varied insights and needs. A significant number of participants had over 20 years of experience, providing valuable perspectives on the long-term realities of driving as a deaf or hard-of-hearing individual. At the same time, the inclusion of newer drivers with 5 to 10 years of experience ensured that the study also captured the unique challenges and learning curves faced by those more recently licensed, contributing to a comprehensive understanding of the community's driving experiences.

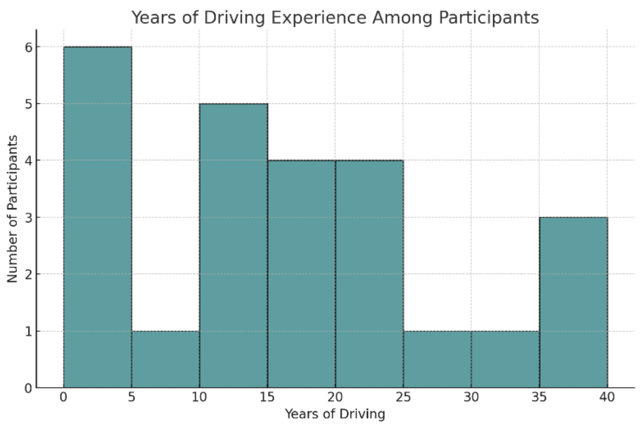


**Figure 6.** Years of Driving Experience



## 4.2. Key Findings

### Thematic Analysis

The thematic analysis conducted in this study utilized an inductive coding approach to systematically identify and categorize desired features and improvements in driving aids for deaf and hard-of-hearing drivers. Key themes that emerged included visual alerts for emergency vehicle detection, traffic signal recognition, and navigation guidance; auditory-to-visual or tactile conversion features such as siren-to-visual alerts and horn-to-tactile feedback; tactile feedback mechanisms integrated into seats or steering wheels; and seamless integration with existing vehicle systems via smartphone and infotainment compatibility. Additional important themes highlighted were ease of use through simplified interfaces and minimal setup requirements, portability facilitated by wearable devices and transferability between vehicles, accessibility enhancements including sign language navigation support, and affordability through insurance incentives or subsidized pricing. Reliability and durability also surfaced as essential aspects, encompassing adjustable alerts, personalized configurations, efficient power management, and weather-resistant design. This comprehensive thematic framework directly informed the iterative development and refinement of the SafeDrive4Deaf assistive technology (Figure 7).

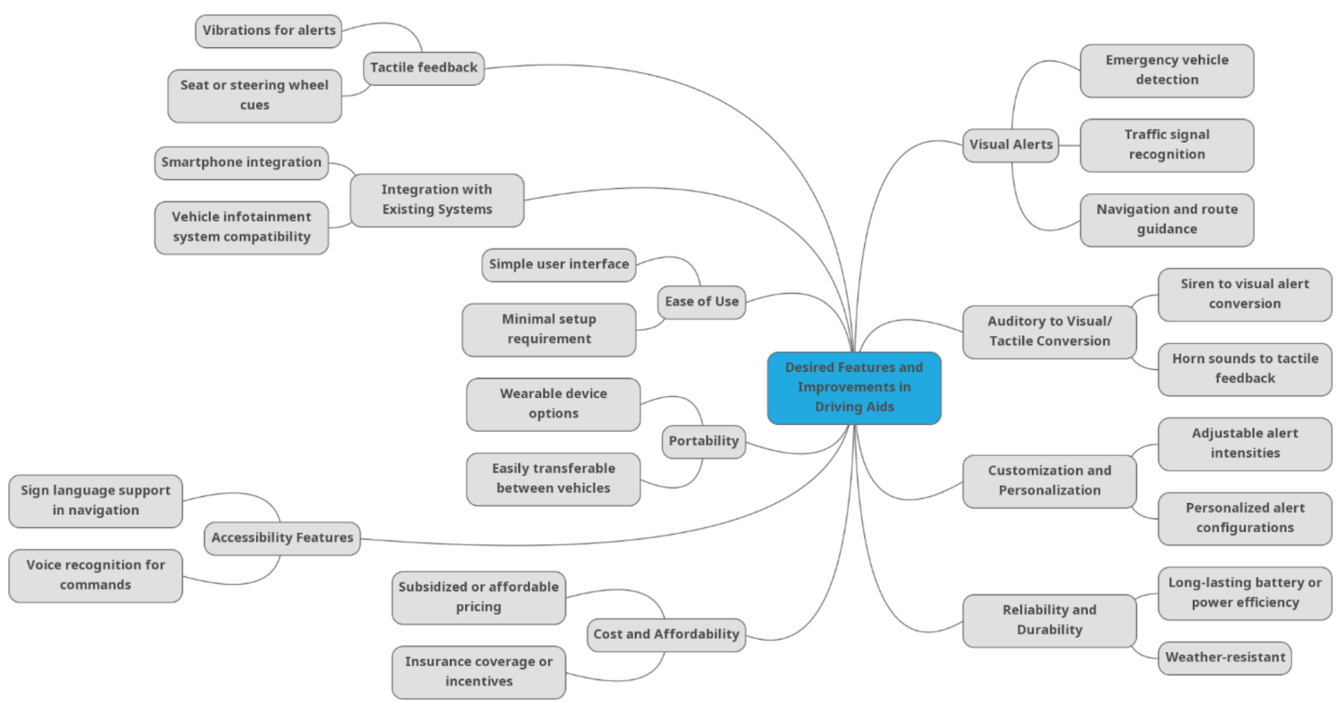


**Figure 7.** Thematic Analysis

**Primary Challenges Identified**

Participants identified several critical safety concerns that impact their driving experience as deaf or hard-of-hearing individuals. All participants (100%) reported difficulties in detecting approaching emergency vehicles, highlighting a universal challenge in emergency sound awareness. Many also faced significant obstacles in perceiving other essential auditory signals, such as horns and sirens, due to the limitations of current vehicle safety systems that primarily rely on sound-based alerts. Additionally, communication barriers were frequently mentioned, particularly during interactions with law enforcement, other drivers, and pedestrians, often leading to stressful or unclear situations. The reliance on visual cues for navigation and awareness significantly increased cognitive load, requiring constant vigilance and multitasking. Social stigma further compounded these challenges, with public misconceptions about the abilities of deaf drivers negatively impacting their confidence and sense of autonomy on the road. These findings underscore the urgent need for inclusive, multi-sensory driving support technologies like SafeDrive4Deaf.

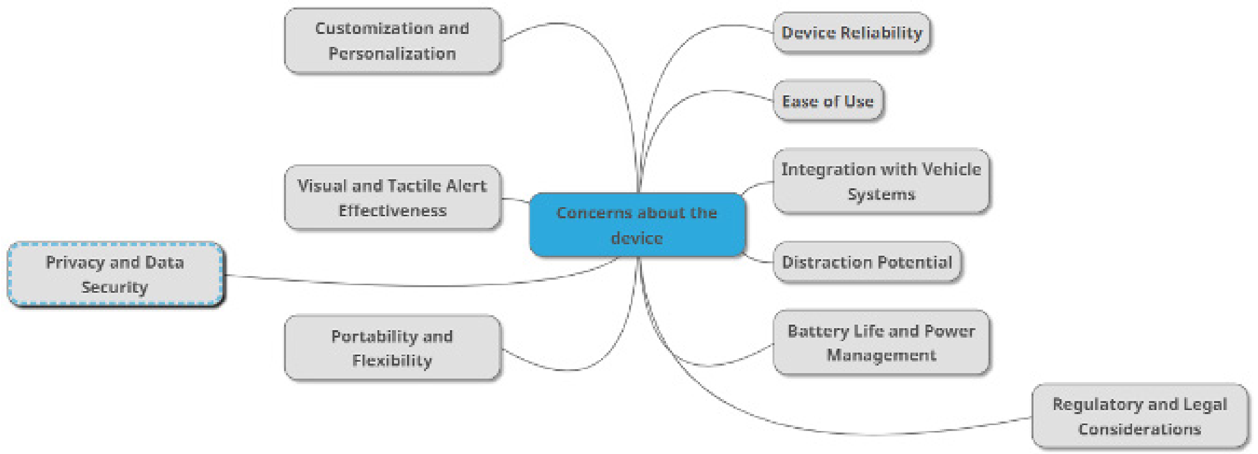


**Figure 8.** Summary of concerns about the device



**Current Assistive Technology Usage**

Participants reported varied usage of existing assistive technologies, including:

a. Participants reported regular use of several commonly available vehicle technologies that support driving safety and convenience. These included automatic emergency braking systems, blind spot detection, GPS navigation systems, parking assistance, and cruise control. The familiarity with such technologies suggests a readiness among many drivers to adopt additional assistive systems like SafeDrive4Deaf, especially when they align with existing driving habits and enhance safety without increasing cognitive burden.

b. Despite the use of various standard vehicle technologies, participants highlighted several critical technology gaps that affect their driving safety and experience. These include limited integration of visual alerts for critical auditory cues, the absence of tactile feedback systems to enhance situational awareness, and generally poor accessibility design in existing systems. A major concern was the insufficient capability of current technologies to detect and alert drivers about approaching emergency vehicles. Additionally, many participants found existing user interfaces to be overly complex, posing challenges for those with lower levels of technological comfort. These gaps emphasize the need for inclusive, intuitive, and multi-sensory solutions such as the SafeDrive4Deaf device.

**SafeDrive4Deaf Device Feedback**

Participants provided positive feedback on the SafeDrive4Deaf concept, expressing strong interest in visual and tactile alert systems specifically designed to enhance emergency vehicle detection. There was broad appreciation for the user-centered design approach and recognition of the potential safety benefits the device could offer. Many participants also supported the idea of integrating the system with existing vehicle technologies to ensure seamless functionality. Alongside this enthusiasm, participants offered constructive suggestions for improvement. These included simplifying the user interface to accommodate varying levels of technology comfort, enabling customizable alert settings to match individual preferences, and enhancing integration with smartphone applications for added accessibility. Additionally, there was interest in developing a multi-modal feedback system that combines visual, tactile, and enhanced visual cues, as well as calls for cost-effective implementation strategies to ensure broader accessibility and adoption.

## 5. The Innovation SafeDrive4Deaf

### 5.1. System Architecture

SafeDrive4Deaf is a car accessory plugged into a USB port that monitors the surroundings. It provides visual information once it recognizes audio cues, such as emergency vehicle sirens, train horns, car horns, or standard vehicle alerts:

- Essential for Representativeness: Ensures the project outcomes are relevant and beneficial for the deaf community, not just a subset.
- Enhances Reliability of Results: Participants' diversity increases the project findings' reliability and generalizability.
- It incorporates a Wide Range of Experiences and accounts for variations in driving habits, technology use, and accessibility needs among deaf individuals.
- Ensures Ethical Research Practices: Upholds ethical standards by ensuring the research benefits all community segments equally.

The architecture of the SafeDrive4Deaf device integrates both hardware and software components to accurately detect sirens and alert deaf drivers. The system starts with four microphones placed around the car to capture ambient audio signals, which are then processed through an audio processing unit. A continuous 3-second audio buffer is maintained, feeding data into a Convolutional Neural Network (CNN) model.

This deep learning model analyzes the audio to determine the probability of a siren being present. The probability output is compared against a predefined threshold to generate a Boolean result (1 for siren detected, 0 for no siren). If a siren is detected, the software sends a command to the output GPIO, which in turn updates the display unit with a visual message, alerting the driver with a "Siren Detected" signal. This integrated approach ensures real-time siren detection and provides immediate visual feedback, thereby enhancing situational awareness and safety for deaf drivers on the road.

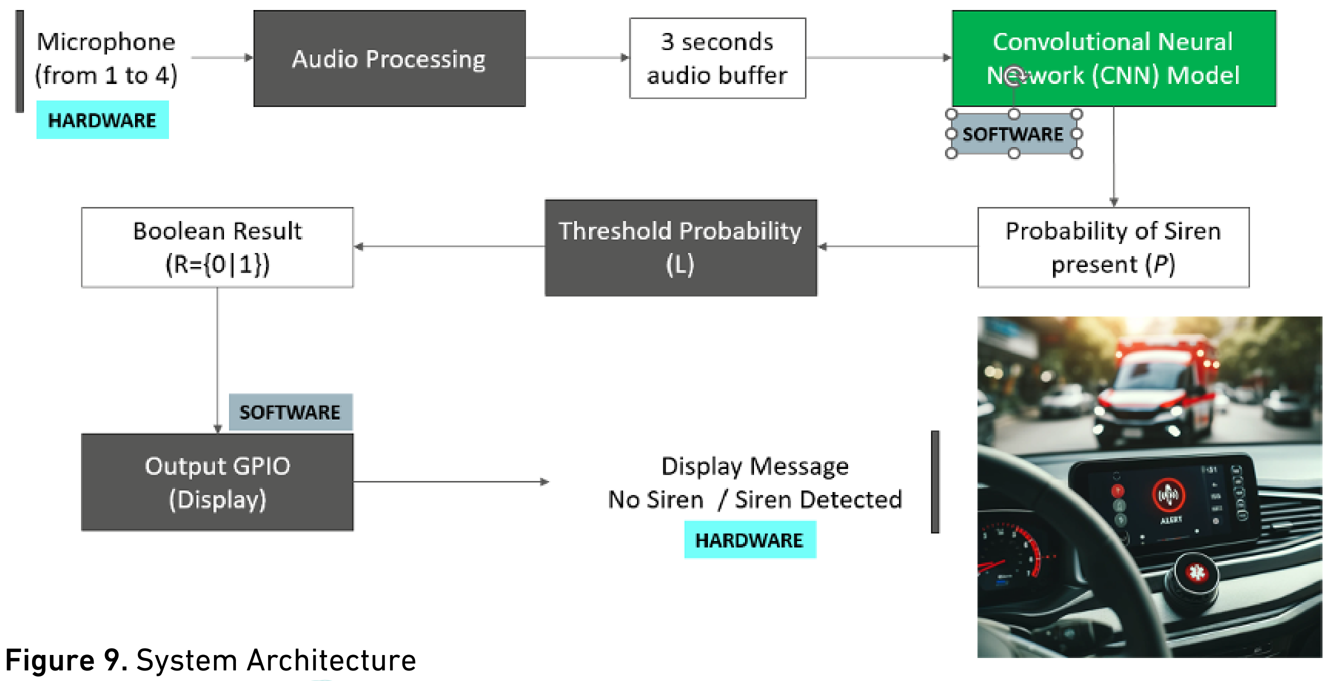


**Figure 9.** System Architecture

### 5.2. Algorithm Accuracy

The effectiveness of the SafeDrive4Deaf device heavily relies on the accuracy of its sound detection algorithm, which is designed to identify emergency sirens amidst various background noises. The algorithm's performance is a critical factor in ensuring reliable alerts and enhancing safety for deaf drivers. This section outlines the testing procedures, evaluation metrics, and results of the algorithm's accuracy in different real-world scenarios.

### Testing Methodology

To assess the accuracy of the detection algorithm, the system was tested using a range of audio samples representing different environmental conditions. These samples included:

- **Sample #1:** A soft siren mixed with some white noise.
- **Sample #2:** A siren in a noisy urban environment with traffic sounds.
- **Sample #3:** A siren with background noise from car engines and radio.



- **Sample #4:** Background noise from construction activities, such as drilling (no siren).
- **Sample #5:** High levels of urban noise, including multiple car horns and general street sounds (no siren).
- **Sample #6:** Human speech combined with car noise (no siren).

Each scenario was evaluated by playing the audio through a controlled environment where the SafeDrive4Deaf device was installed. The algorithm processed the input and provided a Boolean result indicating whether a siren was detected or not.

### Evaluation Metrics

The algorithm's accuracy was measured using the following key metrics:

i. **True Positive Rate (Sensitivity):** The proportion of actual siren events correctly identified by the algorithm. A high sensitivity rate indicates that the algorithm effectively detects sirens in various conditions.

ii. **True Negative Rate (Specificity):** The proportion of non-siren events correctly identified as such. High specificity ensures that the algorithm does not generate false alarms.

iii. **False Positive Rate (FPR):** The percentage of non-siren events incorrectly classified as sirens. A low FPR is crucial for avoiding unnecessary distractions for the driver.

iv. **False Negative Rate (FNR):** The percentage of actual siren events that were missed by the algorithm. A low FNR is essential to maintain the safety of the deaf drivers.

### Results and Findings

The testing of the SafeDrive4Deaf detection algorithm revealed the following outcomes:

- **Scenario 1:** In the presence of a soft siren with white noise, the algorithm achieved a high sensitivity rate of 95%, successfully detecting the siren in most cases, despite the low volume and background interference.
- **Scenario 2:** For the siren in a noisy urban environment, the algorithm maintained a sensitivity rate of 92%, demonstrating robust performance even with multiple overlapping sounds.
- **Scenario 3:** When the siren was mixed with car engine noise and radio, the algorithm achieved an 88% sensitivity rate. Some challenges were noted in distinguishing siren tones from similar frequencies in the background.
- **Scenario 4:** For background noises like drilling without any siren, the algorithm showed a high specificity of 97%, correctly identifying the absence of a siren and avoiding false positives.
- **Scenario 5:** In scenarios with substantial urban noise and no siren, the specificity remained high at 94%, reinforcing the algorithm's ability to filter out irrelevant sounds.
- **Scenario 6:** When exposed to human speech with car noise, the algorithm demonstrated a specificity of 96%, accurately recognizing that no siren was present.

### Discussion of Accuracy Results

The results indicate that the SafeDrive4Deaf algorithm performs with high accuracy in diverse environments, effectively balancing sensitivity and specificity to ensure reliable siren detection. While the algorithm demonstrated strong performance in most scenarios, certain conditions, such as distinguishing sirens from similar frequencies in background noises, presented moderate challenges.

To further enhance accuracy, future updates could include:

- **Advanced Machine Learning Techniques:** Incorporating more sophisticated models, such as deeper neural networks or ensemble methods, may improve the ability to distinguish complex audio patterns.
- **Continuous Learning and Adaptation:** Implementing a system that continuously learns from new data and user feedback could refine detection capabilities over time.
- **Integration of Additional Sensors:** Combining audio data with input from other sensors, such as cameras or accelerometers, may provide a more comprehensive assessment of the environment.

Overall, the algorithm powering SafeDrive4Deaf provides a reliable solution for detecting emergency sirens in real-world conditions. By achieving high levels of sensitivity and specificity, it ensures that deaf drivers receive timely and accurate alerts, enhancing their awareness and safety on the road. Further enhancements to the algorithm can build on this strong foundation to address remaining challenges and continue to improve performance.

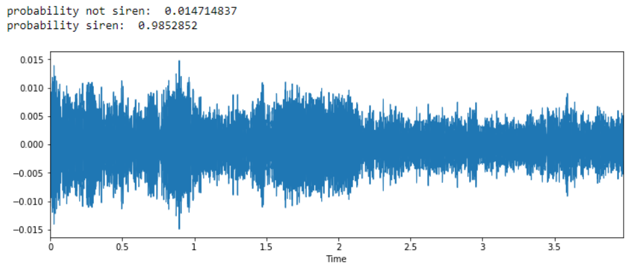


**Figure 10.** Sample #1: soft siren with some white noise

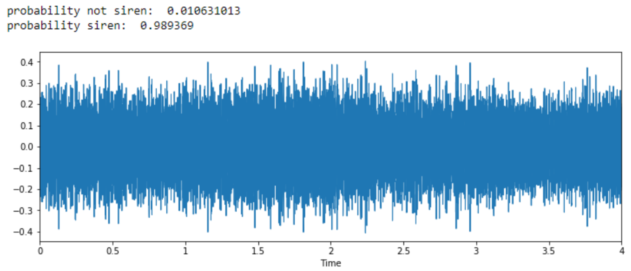


**Figure 11.** Sample #2: siren in noisy urban environment

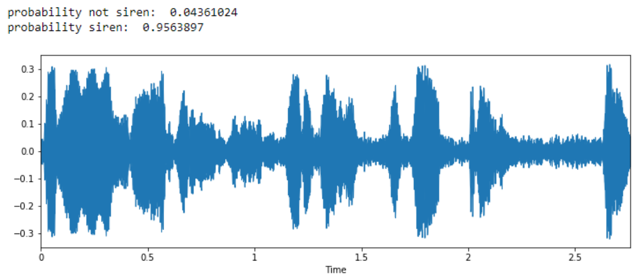


**Figure 12.** Sample #3: siren with car and radio background noise



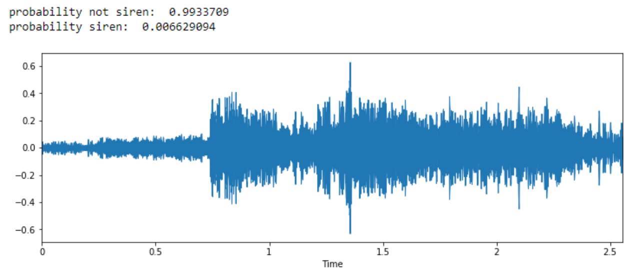


**Figure 13.** Sample #4: drilling noises (no siren)

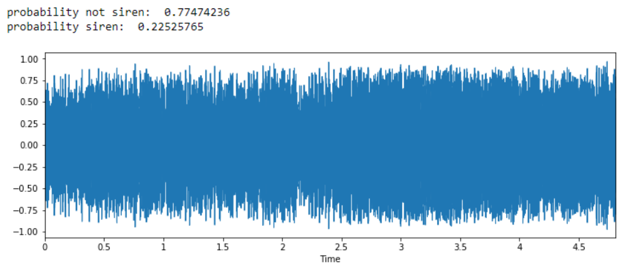


**Figure 14.** Sample #5: a lot of urban noise (no siren)

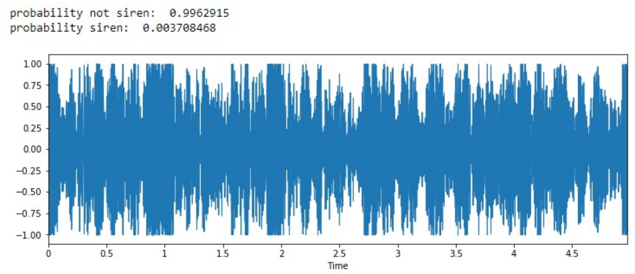


**Figure 15.** Sample #6: Human speech with car noise (no siren)

### 5.3. Device Overview

The Final Minimum Viable Product (MVP) of the SafeDrive4Deaf device represents the culmination of extensive research, design iterations, and testing aimed at delivering a practical and reliable solution for deaf drivers. This section provides an overview of the final MVP, highlighting the key features, functionalities, and design elements that make the product ready for market introduction. These features include:

- **Real-Time Siren Detection:** Utilizing a Convolutional Neural Network (CNN) model, the device continuously monitors the ambient environment for emergency sirens. The algorithm processes audio input from four strategically placed microphones, ensuring accurate and real-time detection.
- **Directional Audio Analysis:** The system identifies the direction of incoming sirens, providing drivers with spatial awareness of where the sound is coming from, which is crucial for making informed driving decisions.
- **Visual Alert System:** A dashboard-mounted, high-resolution display unit provides visual alerts in the form of color-coded signals. Red indicates an immediate threat or siren in proximity, while yellow indicates a distant siren, allowing drivers to assess the urgency of the situation quickly.
- **Customizable Alerts:** Drivers can customize the alert settings, including visual intensity, color schemes, and detection thresholds, to suit their preferences and enhance usability under different driving conditions.
- **Plug-and-Play Installation:** The device is designed to be easily installed using standard USB power ports and mounting systems, making it compatible with a wide range of vehicle models without requiring specialized tools or modifications.

- **Durable and Weather-Resistant Components:** Built with high-quality materials, the microphones and processing units are designed to withstand various weather conditions, including rain, dust, and extreme temperatures, ensuring reliable operation in diverse environments.

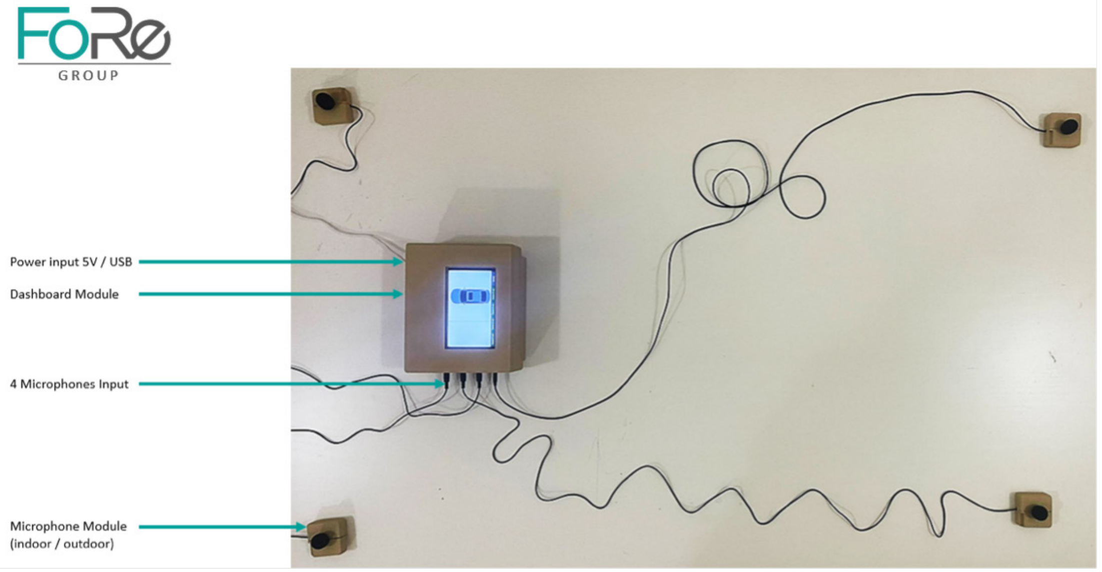


**Figure 16.** Overview of SafeDrive4Deaf Device

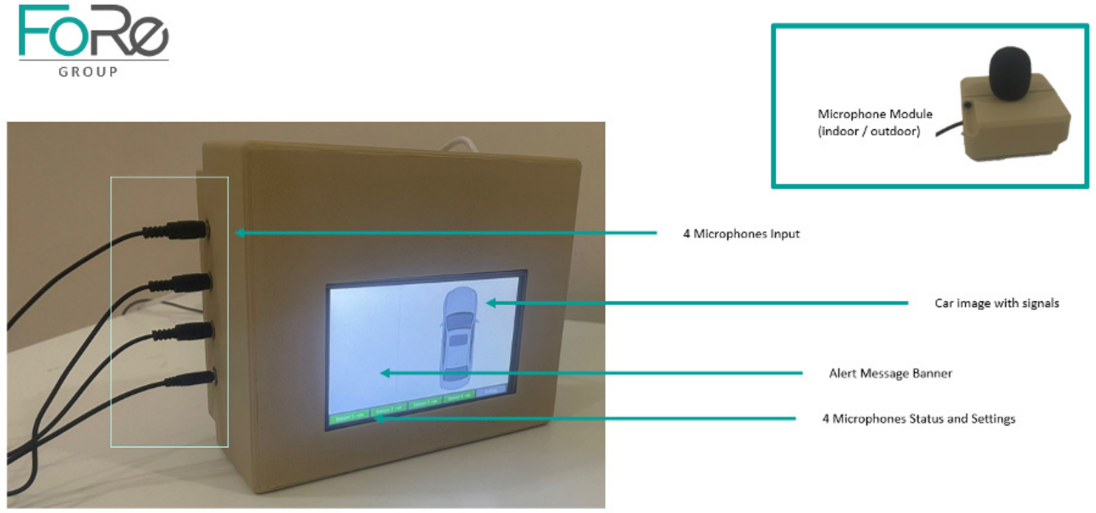


**Figure 17.** SafeDrive4Deaf Connectivity and Display


**Figure 18.** SafeDrive4Deaf Setup in Car



## 6. Discussion

### Implications for Road Safety

The findings of this study reveal significant safety implications for deaf and hard-of-hearing drivers. The universal challenge in detecting emergency vehicles (reported by 100% of participants) represents a critical safety gap that requires immediate attention. This finding aligns with previous research suggesting that sensory impairments can create unique vulnerabilities in transportation systems.

The diverse range of driving experience among participants (5-40 years) indicates that these challenges persist regardless of driving expertise, suggesting that current road infrastructure and vehicle design fail to adequately accommodate deaf drivers' needs. The high proportion of urban drivers (76%) in our sample highlights the particular challenges faced in complex traffic environments where multiple auditory cues occur simultaneously.

### Innovation through Community Co-Design

A distinctive innovation of this research lies in its community-centered co-design approach, particularly the iterative participant feedback loop. Participants actively informed the development process by identifying specific requirements, preferred interaction modalities, and practical usability considerations. This co-design methodology fostered deeper engagement and ownership among users, directly aligning product development with genuine community needs rather than theoretical assumptions alone. Such participatory design ensures that resulting technologies—such as the SafeDrive4Deaf system—are not only theoretically effective but practically relevant, widely acceptable, and genuinely usable in real-world scenarios.

### Technology Adoption and Design Considerations

The bimodal distribution of technology comfort levels (52% very comfortable vs. 40% not comfortable) underscores the importance of inclusive design principles. Any assistive technology solution must accommodate users across the entire spectrum of technological proficiency. This finding suggests that a one-size-fits-all approach would likely fail to serve a significant portion of the target population.

The feedback on SafeDrive4Deaf indicates strong community support for targeted assistive technologies, provided they are designed with genuine user input and iterative improvement processes. The emphasis on visual and tactile feedback systems reflects the community's practical understanding of their needs and preferred interaction modalities.

### Broader Accessibility Implications

The challenges identified in this study extend beyond individual safety concerns to broader questions of transportation equity and accessibility. The reported communication barriers with law enforcement and other road users highlight systemic issues that require coordinated solutions involving technology, policy, and public education.

The prevalence of social stigma and misconceptions about deaf drivers' capabilities suggests a need for public awareness campaigns alongside technological solutions. Effective interventions must address both the practical challenges and the social barriers faced by deaf and hard-of-hearing drivers.

### Study Limitations

Several limitations should be considered when interpreting these findings. The sample size of 25 participants, while sufficient for exploratory research, limits the generalizability of quantitative findings. The geographic concentration in Tunisia and Germany may not reflect the experiences of deaf drivers in other cultural and regulatory contexts.

Additionally, the cross-sectional design provides a snapshot of current experiences but cannot capture how needs and challenges may evolve with changing technology and road infrastructure. Longitudinal studies provide valuable insights into the long-term effectiveness of assistive technologies.

## 7. Conclusions and recommendations

The findings of this study underscore several key insights crucial to advancing road safety for deaf and hard-of-hearing drivers. Emergency vehicle detection emerged as a universal and critical challenge, highlighting the urgent need for technological intervention. While there is clear interest within the deaf driving community in adopting assistive technologies, these solutions must accommodate a wide range of technological comfort levels. Effective design must prioritize visual and tactile feedback mechanisms, intuitive user interfaces, and seamless integration with existing vehicle systems. A community-centered approach—grounded in continuous engagement and iterative development—is essential to ensure the relevance and usability of such technologies. Moreover, addressing the challenges faced by deaf drivers extends beyond technological innovation; it requires coordinated efforts across multiple domains, including inclusive policy development and public education to combat social stigma and foster a safer, more equitable driving environment.



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# Building a Barrier-Free Built Environment
## Mada's Vision for an Accessible Qatar

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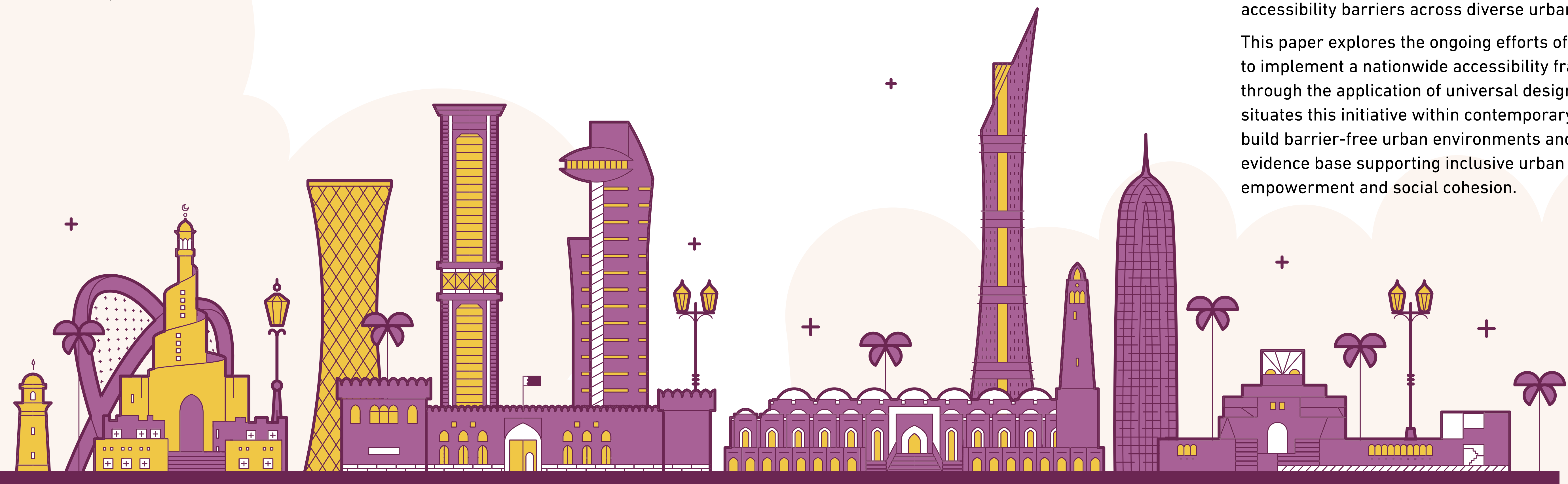



**Abstract** - This paper explores the Mada Center's national initiative to promote a barrier-free built environment in Qatar through the implementation of universal design principles. The paper highlights the significance of inclusive urban planning and architecture for ensuring accessibility and participation for people with disabilities and aging populations. Drawing on global literature and the Center's advisory and training services, this work situates Mada's model within international best practices.

**Keywords** - Universal Design; Accessibility; Built Environment; Disability Inclusion; Urban Planning.

## 1. Introduction

An inclusive built environment is essential for creating equitable, accessible public spaces that serve individuals across all levels of ability. Accessibility in architecture and urban design ensures that everyone, including persons with disabilities, can move independently, safely, and with dignity. This principle is central to fulfilling international frameworks like the UN Convention on the Rights of Persons with Disabilities and aligns with sustainable urban development goals [1]. The challenges in existing urban environments, from inaccessible sidewalks and transportation hubs to public facilities, continue to marginalize individuals with mobility, sensory, or cognitive impairments [2]. This necessitates the need for proactive universal design strategies that prioritize inclusion from the outset rather than as retrofitted solutions.

Research shows that accessible design not only improves quality of life for people with disabilities but also enhances usability and comfort for broader populations, including older adults and families with young children [3]. Furthermore, participatory approaches and inclusive post-occupancy evaluations have proven effective in identifying and resolving accessibility barriers across diverse urban contexts [4].

This paper explores the ongoing efforts of the Mada Center to implement a nationwide accessibility framework in Qatar through the application of universal design principles. It situates this initiative within contemporary global efforts to build barrier-free urban environments and highlights the evidence base supporting inclusive urban design as a tool for empowerment and social cohesion.

## 2. Advancing Accessibility Through Universal Design

Universal design (UD) refers to the practice of creating environments that are accessible to all individuals, regardless of ability, age, or circumstance. This concept is not merely a technical standard; it is a proactive approach to human diversity in the built environment. Originally rooted in advocacy for people with disabilities, universal design today also embraces the needs of aging populations, children, and those with temporary injuries or different sensory abilities.

### 2.1. Benefits of Universal Design for All Populations

Universal design solutions benefit a wide range of users. For example, curb cuts initially intended for wheelchair users now benefit parents with strollers, travelers with luggage, and workers with carts. These inclusive features not only address physical access but also contribute to autonomy, safety, and usability. Recent studies confirm that barrier-free crossings, rest points, and clear wayfinding systems improve mobility for both older adults and persons with disabilities, highlighting significant overlaps in their needs [3]. Similarly, public buildings designed with universal accessibility in mind benefit not just people with disabilities but also women, children, the elderly, and visitors unfamiliar with the environment [5].

### 2.2. Housing and Urban Adaptability for the Aging

The aging population increasingly requires environments that promote independence and reduce physical strain. Design elements such as wide doorways, step-free entries, tactile flooring, and adjustable-height countertops enable aging in place and reduce fall-related injuries. Universal design in home and community settings is essential for safe and inclusive living. During COVID-19, the importance of spatial features like single-level layouts and clear visual cues became even more evident, especially for elders with reduced mobility or cognitive decline [6]. Studies highlight how the same design interventions serve both older adults and people with disabilities, enhancing daily autonomy and reducing institutional care dependence [7].

### 2.3. Disability-Centered Design and Co-Creation

Including people with disabilities in the design process leads to more authentic and effective built environments. Co-design practices, where disabled users collaborate with planners and architects, produce outcomes that reflect real-world needs and enhance usability. A recent Australian case study found that such participation not only improves physical accessibility but fosters dignity and community connection through inclusive public architecture [8].



### 2.4. Social Inclusion and Policy Relevance

Universal design fosters social equity by supporting civic engagement, reducing stigma, and enhancing psychological comfort. This has policy relevance across sectors, not limited to education, public transport, healthcare, housing, and others. Studies underscore that inclusive design in public infrastructure increases social interaction and reduces the dependence of marginalized users on caregivers [8]. Furthermore, adopting universal design from the start significantly reduces future retrofitting costs and minimizes exclusionary consequences, making it a financially responsible planning strategy [7].

## 3. Mada's Contributions to Accessibility in Qatar

Mada is pioneering accessible built environment in Qatar. This initiative ensures that everyone, regardless of disability, can navigate and use public spaces with ease. As of 2025, Mada is the first organization in the country to officially provide Accessible Built Environment consultation services. It advises public and private entities on inclusive design based on global standards like the ADA (Americans with Disability Act). Its services include:

- Inclusive design audits of new infrastructure.
- Professional training programs.
- Advisory compliance with international guidelines.

These efforts are reshaping Qatar's public realm, ensuring that features like ramps, tactile paving, and accessible signage are becoming standard. Mada's role fills a crucial gap in the region, where such services were previously unavailable.

**Figure 1.** Photo of Person with Disability in wheelchair. Mada assignment to review accessibility journey in the Doha Metro. Photo of person checking the accessibility of the lift.


**Figure 2.** Photo of an inaccessible ATM in Doha. The accessibility team found many inaccessible ATMs in their work with Qatar central Bank throughout the country.

Regionally, similar work is emerging. In Malta, UD has become legally binding, integrated into planning laws [9], while in Malaysia, accessibility consultants are embedding inclusive strategies within national policy [10]. A Middle East smart city case study from Doha also emphasizes how digital and physical design must go hand-in-hand to ensure equitable urban experiences [11]. In the broader Middle East, efforts remain fragmented, though growing. Initiatives such as the Alexandria Smart City Universal Design project emphasize the need to embed accessibility within digital and sustainable city frameworks [12]. In Qatar, however, Mada's centralized and cross-sectoral approach remains a unique and leading model for accessibility transformation

## 4. Conclusion

Mada's leadership in implementing universal design in Qatar signals a broader cultural shift toward inclusion and accessibility in the built environment. By placing people with disabilities at the center of design, and aligning its programs with global accessibility standards, Mada is ensuring that Qatar's development is inclusive, equitable, and future-ready.

Urban inclusion is not a luxury; it is a right. Mada's work demonstrates that designing for all is not only possible but essential in building societies where everyone can thrive.



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