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Vehicular Inclusion: an Analysis of Deaf Driving and Prospects for More Accessible Mobility

Inclusión Vehicular: un Análisis de la Conducción por Personas Sordas y Perspectivas para una Movilidad Más Accesible

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Abstract

This article analyzes the feasibility of driving for individuals with hearing impairments by identifying challenges, technological adaptations, and regulations that facilitate their vehicular inclusion. Studies indicate that although deaf individuals do not perceive auditory signals, they develop enhanced visual perception to compensate for this limitation on the road. The importance of interdisciplinary evaluations and technological adaptations, such as visual alert systems, is emphasized to ensure safe driving. In Colombian context, regulations such as Law 1618 of 2013 and recent resolutions have advanced the accessibility of driver's licenses for this population, promoting their autonomous mobility. However, challenges persist, particularly regarding communication barriers in training and certification processes. This underscores the need to continue fostering inclusive technologies and regulatory frameworks to enhance equity in access to vehicular mobility.

Keywords: inclusion, driving, hearing impairment, technological adaptations.

Resumen

El objetivo del artículo es analizar la viabilidad de la conducción por parte de personas con discapacidad auditiva, identificando los desafíos, adaptaciones tecnológicas y normativas que faciliten su inclusión vehicular. Los estudios revisados evidencian que, aunque las personas sordas no perciben señales auditivas, desarrollan una mayor capacidad visual que les permite compensar esta limitación en la vía. Se destaca la importancia de evaluaciones interdisciplinarias y adaptaciones tecnológicas, como los sistemas de alerta visual, para garantizar una conducción segura. En el contexto colombiano, normativas como la Ley 1618 de 2013 y resoluciones recientes han permitido avances en la obtención de licencias para esta población, promoviendo su movilidad autónoma. Sin embargo, persisten desafíos relacionados con barreras comunicativas en los procesos de formación y certificación. Esto resalta la necesidad de seguir impulsando tecnologías inclusivas y marcos normativos adecuados para fortalecer la equidad en el acceso a la conducción vehicular.

Palabras clave: inclusión, conducción, discapacidad auditiva, adaptaciones tecnológicas.

1. Introduction

A primary challenge for deaf individuals is communication (Jaimes & Sánchez, 2020; Rodríguez-Bernal & Zambrano-Santiago, 2021), as this barrier affects both interpersonal relationships and self-expression. Thus, it is essential to develop alternative linguistic methods, such as manual gestures, to facilitate their participation in social activities, including understanding driving instructions (Otoom et al., 2022). Sign language plays a crucial role in bridging communication gaps between deaf and hearing individuals across various social contexts (Muñoz-Galíndez & Vargas-Cañas, 2023). However, the presence of sign language interpreters remains essential in settings where sign language proficiency is lacking (Fullwood et al., 2023).

Effective communication is fundamental to personal, professional, and social development. Consequently, individuals with hearing impairments face significant disadvantages, given their sensory limitations and structural alterations in the auditory system that hinder sound-based communication (Andrade-Sánchez, 2015). The inability to communicate orally—widely considered the "normal" mode of expression—poses challenges in various situations requiring verbal interaction, such as medical consultations, customer service interactions, classrooms, and driving-related instructions (Jaimes & Sánchez, 2020; Neme & Romero, 2021). However, these barriers can be mitigated through alternative communication methods such as writing, visual demonstrations, and expressive gestures (Andrade-Sánchez, 2015).

As noted by Melero et al. (2022), individuals with normal hearing can perceive sounds below 20 decibels (dB). Hearing-impaired individuals, however, exhibit varying degrees of hearing loss. Those with hearing thresholds between 20- and 40-dB struggle with distant sounds and often require assistive devices. Individuals with hearing limitations between 40 and 70 dB primarily perceive loud vibrating sounds, making interpersonal communication difficult without hearing aids (Albash, 2023). Those with hearing thresholds between 70- and 90-dB experience near-total auditory impairment, necessitating clinical intervention (Fullwood et al., 2023).

Hearing loss can be congenital, resulting from genetic factors or complications during pregnancy and childbirth (Kale, 2014) or acquired due to diseases, head trauma, or infections during childhood or adulthood (Alsulaiman et al., 2023).

In Colombia, Law 1618 of 2013 ensures social inclusion by granting individuals with disabilities equal opportunities to interact in various social settings without restrictions due to impairments (Congreso de Colombia, 2013). This legal framework is crucial in establishing inclusive policies that address the specific needs of individuals with disabilities.

In an evolving world, innovation and inclusion are essential for fostering independence and safety within the deaf community (Otoom et al., 2022). Accordingly, an in-vehicle training approach incorporating visual assistive technologies, technological tools, and sign language instruction has been explored to empower deaf drivers. This approach enhances their ability to comprehend driving procedures through visual cues and interactive learning resources (Driving Instructors, 2022). The objective is to foster independence and confidence in mobility, enabling deaf individuals to experience greater autonomy in daily life (Allen, 2016).

Given the need for self-sufficient transportation, the right to drive should be extended to all individuals capable of operating a vehicle without cognitive or motor impairments (Chong & Hussain, 2022). When limitations exist, appropriate adaptations must be implemented to ensure safe driving (Alsulaiman et al., 2023). However, many countries prohibit deaf individuals from obtaining a driver's license due to prevailing biases within traffic authorities and licensing institutions (Otoom et al., 2022). These restrictions are often imposed without empirical evidence supporting the claim that deaf drivers pose a greater risk on the road. Denying driver's licenses significantly impacts employment opportunities, mobility, and social participation (Allen, 2016).

Despite auditory limitations, deaf individuals possess an enhanced visual awareness, which compensates for their inability to perceive auditory signals. Studies indicate that deaf drivers develop heightened visual perception, enabling them to process environmental cues more efficiently (Gustavsson & Nielsen, 2000).

For deaf individuals to obtain a driver's license, specific requirements must be met, including evaluations by interdisciplinary teams (physiatrists and occupational therapists) to assess their driving capabilities. These evaluations should be conducted with the assistance of sign language interpreters when necessary. Additional requirements include specialized training, vehicle adaptations, and instruction through certified driving schools catering to hearing-impaired individuals (Driving Instructors, 2022). If hearing loss exceeds 45% (with or without hearing aids), adaptations such as panoramic interior mirrors and external side mirrors are recommended to optimize visual perception.

During driver training, deaf individuals rely on visual indicators for essential driving operations, including gear shifts, acceleration, and braking. They must also be trained to recognize visual cues for emergency vehicles, such as monitoring mirrors for flashing lights and observing other drivers' reactions (Road Safety Authority, 2019).

In Colombia, Resolution 20223040030355 of May 31, 2022, established that deaf individuals are legally permitted to obtain a driver's license after completing a certified theoretical and practical training program (Mintransporte, 2022).

This study examines the feasibility of driving for individuals with hearing impairments by identifying challenges, technological adaptations, and regulatory frameworks that facilitate their vehicular inclusion. To achieve this, the study analyzes the experiences and perceptions of deaf drivers, evaluates existing regulations, and reviews applied strategies. The findings aim to contribute to the development of more accessible and inclusive mobility policies.

2. Methodology

This research was based on a documentary review of experiences and regulations related to the inclusion of deaf individuals in motor vehicle driving. The methodological process followed the phases of search, identification, selection, analysis, and interpretation of information (Osorio-Andrade et al., 2024).

The initial search was conducted in Scopus, Web of Science, Springer, and SciELO databases, given their extensive dissemination of high-impact research in the field. The following search descriptors were used: "Driving of deaf people," "Driving license + Hearing impairment," "Driving in non-hearing people," and "Inclusion of non-hearing people." The inclusion criteria considered studies published within the last ten years focusing on practical learning for deaf individuals in driving contexts. Research articles were selected based on their relevance in addressing the diagnosis and mechanisms employed to facilitate driving instruction for this population.

A total of eight articles met the inclusion criteria, with studies originating from European countries, the United States, and Brazil. The selected articles were systematically organized into an Excel database for further analysis. Each entry recorded key information, including author(s), year of publication, geographic location, primary findings, and resolution mechanisms implemented to support deaf individuals in learning to drive.

In other hand, the review process involved a primary search using structured search equations. The titles and abstracts of retrieved articles were screened, selecting those with a high probability of providing relevant information to the study. Due to the limited availability of literature directly related to the topic, all articles explicitly addressing the inclusion of deaf individuals in driving were registered in the database, while unrelated studies were excluded.

The results are presented through a narrative synthesis, categorizing key findings based on the processes, diagnostic criteria, and resolution mechanisms identified in the reviewed literature.

3. Results and Discussion

3.1 Technological barriers and solutions for driving

The analysis includes eight studies conducted in different regions worldwide, revealing that while deaf individuals face significant barriers in automotive driving, various technological and methodological solutions have been implemented to enhance accessibility and driving safety. This review provides a comprehensive overview of the strategies developed to support deaf drivers, emphasizing the critical role of assistive technologies in fostering equitable access to mobility.

The reviewed studies highlight multiple challenges and technological advancements for the inclusion of deaf individuals in traffic systems. For instance, Souza et al. (2016) identified substantial obstacles in both the acquisition and renewal of driver's licenses for deaf individuals, as well as in their daily interactions within traffic systems. Participants in their study reported that the absence of sign language interpreters and non-adapted theoretical tests create significant barriers to obtaining a driving license. Additionally, the study underscores the importance of specialized training for driving instructors and examiners, along with the incorporation of sign language-based theoretical assessments via video format to enhance accessibility.

In the realm of assistive technologies, Binti Nor Rashid et al. (2024) classified five primary technological solutions designed to improve support and communication for the deaf community: augmented reality, specialized software, websites, mobile applications, and tactile devices. These tools have demonstrated effectiveness in enhancing autonomy and integration across various domains, including driving. A notable example is the research by Otoom et al. (2022), which introduced a vehicular navigation assistive device that translates GPS voice instructions into vibrotactile signals on wristbands. This system achieved a 99% accuracy rate, with an average usability rating of 4.67/5, reflecting high acceptance among deaf users.

Other studies have explored perceptions of driving capabilities among deaf and hearing individuals. Beha (2022) found that both deaf and hearing drivers rate their driving skills as highly proficient. However, hearing drivers expressed concerns regarding the safety of deaf drivers, highlighting prejudices and misconceptions about their capabilities.

In addressing communication barriers, Abbas et al. (2021) developed an Arabic sign language corpus comprising 215 words and phrases across eight categories, including greetings, directions, and transportation-related terminology. The evaluation of this corpus, based on expert validation and Cohen's Kappa coefficient, yielded a concordance level of 61% and an error rate of 10.23%. The integration of linguistic resources like these into AI-driven platforms could significantly improve interaction between deaf drivers and hearing passengers, reducing communication obstacles in vehicular environments.

From a vehicle safety perspective, Salem et al. (2023) developed an IoT-based system capable of detecting critical auditory signals (e.g., emergency sirens and car horns) and converting them into visual alerts on the vehicle dashboard. Using machine learning classification models such as CNN, ANN, KNN, RF, and SVM, the system achieved an accuracy rate of 97%, demonstrating its potential in enhancing environmental awareness for deaf drivers, particularly in high-traffic and noise-intensive settings.

The impact of fatigue on driving performance among hearing-impaired individuals was analyzed by Wei et al. (2024), who investigated adaptive multimodal vehicular interface design strategies. Their findings indicate that fatigue significantly impairs reaction time and driving accuracy, increasing response time to 2.62 seconds while reducing accuracy to 56.88%. However, incorporating high-frequency vibrations (70 Hz) along with visual cues reduced reaction time by 0.428 seconds and improved accuracy by 17.80%, suggesting that optimized multimodal interfaces could be instrumental in creating more inclusive and safer autonomous driving systems.

Moreover, Shetty et al. (2024) evaluated sound localization abilities in simulated traffic environments for individuals with varying degrees of hearing impairment. Their study revealed that sound localization errors increase proportionally with both hearing loss severity and ambient noise levels, significantly impacting speech recognition and the perception of critical road safety sounds. The study further emphasizes that traditional audiograms may be insufficient in assessing auditory aptitude for driving, advocating instead for the integration of auditory localization tests in the licensing process to enhance road safety for hearing-impaired drivers.

3.2 Barriers to obtaining a driver's license

A driver's license is a fundamental document that grants individuals the legal right to operate motor vehicles, promoting autonomy and mobility. However, in many countries, deaf individuals face challenges in obtaining a driving permit due to traditional requirements, such as hearing tests. Fortunately, some nations, including Colombia, have started to revise and adapt their policies to promote greater inclusivity. For instance, Resolution 20223040030355 of May 31, 2022 (MINTRANSPORTE, 2022) has introduced modifications that allow sign language interpreters during licensing exams and visual tests as alternatives to auditory assessments. Additionally, specialized driving evaluations utilizing visual and tactile signals instead of auditory cues are being developed, marking a significant advancement in inclusive mobility policies.

Driving is an activity that demands the rapid integration of cognitive, perceptual, and motor processes, where vision plays a predominant role (Brauer, 2014). Given this, health professionals play a critical role in ensuring traffic authorities have accurate medical assessments for licensing. Their recommendations on medical requirements, adaptations, and driving restrictions are essential for granting licenses under conditions that account for an individual's health limitations (Goodman et al., 2021; Lamus & Gómez, 2019). For instance, individuals with partial hearing loss may be required to use hearing aids, whereas those with bilateral deafness should operate vehicles equipped with visual and tactile alert systems to enhance situational awareness (Brauer, 2014).

International research has provided valuable insights into neural and cognitive differences between deaf and hearing individuals, offering a foundation for developing adaptive solutions to everyday challenges. Often, deaf individuals face exclusion due to prejudices and perceived risks rather than actual driving performance limitations (One House Communications, 2019). Studies from the University of Sheffield (UK), have demonstrated that profoundly deaf individuals tend to develop enhanced peripheral vision, compensating for auditory limitations (Codina et al., 2011). These findings emphasize the need for alternative assessment criteria that consider sensory adaptations rather than relying solely on traditional auditory-based evaluations.

One of the most pressing challenges for deaf drivers is communication, both with other road users and authorities. Limited perception of auditory signals, difficulties in understanding verbal instructions, and the lack of emergency verbal alerts can create risks in critical situations (Driving Instructors, 2022). To address these concerns, assistive technologies have been proposed, including visual alert systems, vibration-based emergency notifications, and AI-driven sign language translation tools (Arias-Salcedo, 2022). However, communication barriers persist in public transportation systems, where oral interactions are often required, reinforcing the necessity for personal vehicle ownership among deaf individuals (Merino-Posligua, 2019; Ramos et al., 2019). Owning a private vehicle enhances independence and flexibility in daily mobility (Martínez, 2010).

To ensure effective learning during driving instruction, it is crucial to develop an adaptive teaching plan tailored to deaf learners (Codina et al., 2011). Driving instructors should consider motor, physical, and physiological factors, utilizing technological aids to improve instructional quality and learner satisfaction

(Luís & Mangas, 2021). Given that deaf individuals rely primarily on visual stimuli, the most effective teaching methods involve visual-based learning, whether through simulated environments or direct vehicle instruction (Gustavsson & Nielsen, 2000).

Although many deaf individuals successfully obtain their licenses, instructional quality can still be improved through the implementation of specialized pedagogical strategies and technological resources (Driving Instructors, 2022). Visual assistance systems and adaptive warning technologies not only enhance safety but also contribute to greater autonomy in daily transportation (San-Segundo, 2009).

Innovative solutions, such as sign language translation software (Bottoni et al., 2013) and mobile learning applications for vocabulary acquisition, illustrate the potential of technology in facilitating communication and enhancing learning for the Deaf community (Goodman et al., 2021). These advancements highlight the importance of innovation and inclusion, ensuring that deaf individuals are fully integrated into society and can exercise their right to mobility without unnecessary restrictions. By adopting inclusive policies, technological advancements, and adaptive teaching methodologies, significant progress can be made in eliminating barriers and ensuring equal opportunities for deaf individuals in driving and mobility.

4. Conclusions

Obtaining a driver's license is a fundamental right that should be accessible to all individuals, including the deaf population, whose mobility needs are equivalent to those of any other citizen. However, traditional evaluation processes, which rely heavily on hearing-based assessments, impose unnecessary barriers that can exclude deaf individuals from independent transportation. To address this issue, the integration of adaptive solutions, such as theoretical and practical methodologies in driving schools and vehicle-assistance technologies, has proven to be an effective approach to ensuring equal access to mobility.

The inclusion of deaf individuals in the driving sector represents a significant advancement toward equity and universal access in transportation systems. Recognizing that driving competence is not solely dependent on hearing challenges, longstanding prejudices and institutional barriers, ultimately fostering greater independence for deaf individuals. The ability to drive not only enhances autonomy but also improves quality of life, expands employment opportunities, and facilitates social participation for this population.

To achieve full integration, it is essential to promote awareness, regulatory improvements, and continuous advancements in assistive technologies that cater to the specific needs of deaf drivers. Encouraging respect, understanding, and inclusive road safety practices will contribute to a more diverse and secure traffic environment. Furthermore, these efforts lay the groundwork for future policies and technological innovations that will promote safe, accessible, and seamless mobility for deaf individuals worldwide.

Authors' contribution

Luis Alberto Quintero-López: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, and Writing - review editing.

José Luis Consuegra-González: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, and Writing - original draft.

Jorge Andrés Silva-Parada: Conceptualization, Investigation, Methodology and Writing - original draft.

Juan Camilo Castro-Barrios: Conceptualization, Investigation, Methodology and Writing - original draft.

Isaac David Oliveros-Quintero: Investigation, Methodology, Validation and Writing - original draft.

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