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Needs of Deaf People Using Elevators: Identification of Accessibility and Safety Requirements

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Abstract: As urbanization and population growth continue, cities concentrate an increasing amount of people, energy, and economy. Multi-story buildings enable densification, requiring vertical transport for access to upper floors. This is crucial for people with disabilities, who may face barriers in the built environment. Elevators are essential for accessibility, allowing everyone, including people with disabilities, to comfortably access multi-story buildings. However, barriers to inclusivity remain, often subtle and hard to define. This paper highlights one such example, focusing on elevator use by individuals with varying degrees of hearing loss. Currently, they cannot establish one-to-one communication with the outside world if trapped in an elevator. Under EN standards, this issue stems from alarm system requirements that lack effective alternatives to voice communication. Based on this evidence, the research was carried out in two steps, with the aim of understanding the needs of deaf individuals when using elevators by directly involving them in the study. First, a questionnaire conducted in Italy collected information regarding the safety and usability of elevators. Second, a test campaign involving both deaf and normal-hearing participants was carried out to quantify the severity of the issue and evaluate potential solutions to address the identified challenges. The conclusions indicate that current alarm systems in elevators are inadequate for individuals with hearing impairments, and effective alternatives must be implemented.

Keywords: environmental accessibility; accessible buildings; elevators; lifts deaf; hard of hearing; alarm system; emergency procedure; classification of needs

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1. Introduction

According to a United Nations study conducted in 2018 [1], 23 percent of the world's population lived in cities with at least 1 million inhabitants, and this number is projected to grow in the foreseeable future. Simultaneously, the amount of population living in rural areas will decrease to 39.6% by 2030 [1]. This means that an increased number of people will live in densely populated areas, where multi-story buildings are the conventional building type. The growth of population, also fueled by the increased life expectancy, is causing the construction of a significant quantity of buildings. To make better use of valuable space in urbanized areas, cities are going through a densification process, with multi-story buildings replacing older low-rise structures.

Among the 17 goals set by the UN Department of Economic and Social Affairs to achieve Sustainable Development [2], target 10.3, is specifically dedicated to equality, with the scope to empower and to promote the social, economic, and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, economic, or other status.

Accessibility involves the attitude to develop the human potential, and it is an instrument of people's accomplishments [3]. Accessibility has a positive meaning linked to the wider participation of people in services and spaces. As a consequence, compromised accessibility of spaces implies the isolation of people with disabilities [4]. This becomes a form of discrimination as sanctioned by the general principles of the convention on the rights of persons with disabilities (CRPD): "accessibility", stand alone, is one of the eight principles as "non-discrimination", "full and effective participation and inclusion in society", and "equality of opportunity" [5].

A key aspect of achieving social and economic inclusion is mobility. In densely populated cities, this involves both horizontal and vertical movement. It is therefore crucial that mobility solutions are accessible to the widest range of individuals. Within buildings, vertical mobility is provided by elevators, which are the sole means of transport to move people efficiently and safely between floors.

Elevators are an essential device to access multi-story buildings, not only for persons with disabilities but also for the general public. Their importance, beyond the stringent needs of persons with disabilities, is demonstrated by data available from real estate associations and an academic study conducted in China [6,7].

Therefore, the more elevators are accessible by the widest range of people, the more buildings become inclusive. This benefits not only individuals with disabilities but also society as a whole by addressing the richness of diversity. The present research stems from systematic observation by the authors. During their decade-long research activity on the integration of elevators in the architectural design of buildings and on accessibility of buildings thanks to elevators [8–11], they encountered several cases of hard-of-hearing people (a term used to describe people with partial hearing loss) or individuals with complete deafness that did not use elevators at all. The reason for this is unclear, and the goal of the present research is to determine whether the observed fact was an isolated yet recurrent circumstance or a common occurrence.

Stemming from this, the research tries to answer the following questions: (1) the frequency of deaf or hard of hearing people who avoid the use of elevators and under what circumstances; (2) the causes of this avoidance that actually limit their capacity to access multi-story buildings; (3) the identification of possible solutions to overcome these circumstances.

1.1. Structure of the Paper

The paper provides a wide perspective of elevator accessibility, identifying an important and easy-to-fix shortcoming in knowledge, usage practices, and legislation/standards. To this end, it addresses, for the first time, the needs concerning elevators for a specific category of users: deaf people and persons with varying levels of hearing loss. The paper is structured in six sections: the Section 1 serves as a background, providing an introductory description of elevators and of their high level of safety. The Section 2 delves into aspects related to the accessibility of elevators, analyzing the international norms and standards that the elevator industry complies with in the design and construction of elevators and their components. The Section 3 identifies the requirements connected with the use of elevators generated by a specific user category: deaf people and those with different degrees of hearing loss. It sets out the methodology adopted for the creation of a questionnaire aimed at collecting information on the human–elevator behavior, describing the results of the questionnaire and how it has been used to prepare the experiment described in the next section of this paper. The Section 4 discusses in detail the results of the questionnaire that has been created to collect data on the interaction of deaf and hard of hearing users with elevators. Section 5 of the paper presents a discussion of the results of the questionnaire that have been validated with an experiment involving people with deaf and hard of hearing individuals and a control group of normal-hearing individuals. The Section 6 presents the conclusions of the paper with a discussion of the new design solutions that the elevator industry should embrace to contribute to a more inclusive society.

1.2. Safety of Elevators

An elevator (called lift in British English) is defined by the EU Directive on the harmonization of the laws of the member states relating to lifts and safety components for lifts as "a lifting appliance serving specific levels, having a carrier moving along guides which are rigid and inclined at an angle of more than 15 degrees to the horizontal, or a lifting appliance moving along a fixed course even where it does not move along rigid guides" [12].

Elevators, unlike cars, are not registered vehicles. Many countries are therefore lacking official figures on the stock of their elevators. When data are available, it is not homogenous, often inconsistent, and based on assumptions and indirectly collected statistics. Italy is often considered the second country worldwide, after China [13], in terms of the number of elevators, with about 1 million in total [14]. Half of these were installed before 1989, when the current legislation on accessibility was introduced. As a result, nearly 500,000 elevators in Italy do not comply with the basic principles of accessibility [15].

Precise data on the safety of elevators for passengers are not collected at an aggregated level in any country, making comparisons purely indicative. In Italy, Anie—one of the three Italian associations of industries operating in the elevator sector—reports that, with approximately 100 million elevator rides per day, the incident rate is 0.00020 per lift (number of accidents divided by number of lifts) [14]. This frequency is comparable to the 0.00024 of elevators installed in the US reported by another unreferenced source [16]. A study conducted by the US-based The Center for Construction Research and Training in 2013 [17] reports that in the United States there is an average of 10 deaths per year associated with elevator passengers (i.e., not people installing or maintaining elevators or buildings) and about 15 deaths per year in workers building or maintaining elevators or their wells. Confirming the lack of uniformly collected data, these differ significantly from more recent data collected by the US Department of Labor, Occupational Safety and Health Administration, that reports only one casualty happened in 2022 and four in 2023 in the US [18] for workers. For the sake of comparison, in similar years in Italy there were 1–2 passenger deaths per year [14], while in more recent years there are no records of passenger deaths due to elevators in 2020, 2021, and 2022 [19], despite a much larger number of elevators installed. A passenger fatality was reported in July 2024, with a woman falling in the shaft when the landing door of an upper floor opened despite the cabin being on the ground floor [20]. The data available are not homogeneous and may be the result of different legislation on the safety of elevators, but it may also suggest—most likely—a further layer of incompleteness and inconsistency in the way data on elevators are collected in each country.

Still, despite this uncertainty of information, elevators represent a very safe means of transportation. However, the advancement of our society requires a continuous effort toward safer and more accessible elevators.

With this in mind, the emergency procedure of elevators, as described in the following section, very rarely includes life-threatening circumstances. Instead, it very much deals with the discomfort and perceived danger of being trapped inside the cabin after a mechanical failure, electrical blackout, or other causes that prevent the opening of doors.

2. Accessibility and Elevators

2.1. Definition of Disability

The ICF-International Classification of Functioning, Disabilities, and Health by the World Health Organization—WHO [21] provides a broad analysis of individual health by establishing the correlation between health and the environment. It defines disability as a health condition in an unfavorable environment. The concept of disability taken into consideration by the WHO is not oriented to highlight the deficits and disabilities that make the living conditions of people precarious but rather to be a concept in an environmental and socially evolving context [22]. This approach is the basis for broadening the concept of disability: the experience of disability over the life-course is a universal human experience, as everyone will face some limitation in bodily or mental function at some point when aging [23].

Moreover, a disability may be permanent or temporary, mild or severe, single or associated with other dysfunctions. In this context, ICF acts as a health classifier, taking into consideration the social aspects of disability. The introduction of the social environment within the official definition of disability has focused attention on the importance of including people with disabilities in social life [24–26].

Becoming an integral member of community life, the person with disabilities should be able to access social life freely and autonomously, as much as possible. According to the World Programme of Action concerning Disabled Persons [27], it is essential to further develop the equalization of people's opportunities in the physical and cultural environment, in housing and transportation, in health, and in social life, including sports and recreational facilities.

As the link between the health of individuals with disabilities and their social integration is a requisite for the quality of their life, the environment as a whole must satisfy the accessibility requirements [28].

2.2. Environmental Accessibility

Environmental accessibility defines the characteristics of the built environment to be accessible with ease, comfort, and safety, autonomously by most people who may have different skills, sensitivity, and capabilities. Accessibility is a universal value and is an inherent right that benefits all [29].

Accessibility is linked to every human activity. Specifically, when considering material goods and spaces, it is a qualifying factor for constructions and objects that promote social inclusion. According to international standards [30–32], environmental accessibility is a quality for which solutions, buildings, structures, and services can be used by people with a wide range of needs and abilities [33].

In order to frame environmental accessibility in the design practice capable of proposing high-performance solutions, the definition of environmental accessibility may include more technical principles. In fact, environmental accessibility highlights the link between the physical characteristics of the environment and the actual and perceived well-being of the person. Following this idea, accessibility represents a class of needs that refers to the multitude of functional requirements that—in addition to usability—concern comfort, safety, orientation, and mobility. The concept of environmental accessibility amplifies the required performance of constructions, introducing performance inherent to the multisensory, cognitive, and perceptive interactions [26]. Environmental accessibility is therefore the result of technological, morphological, and material choices, defined on the basis of multidisciplinary, transdisciplinary, and multi-professional knowledge contributions and supported by experiments with stakeholders and users. This sentence underpins the research presented in this paper.

2.3. Accessibility Through Elevators and the Accessibility of Elevators in the European Standards

The accessibility and safety requirements of elevators have improved over time as a result of the regulatory evolution specific to this industry. In Europe, the accessibility of elevators is regulated by directives [12,34] and mainly by EN technical standards, in addition to the laws of the European member states on accessibility.

The standards dealing with accessibility of elevators for people with disabilities are the following:

1. Directive 2014/33/EU [12]: the Lift Directive is the main reference text for the development of the standards. Among a number of requirements, it states that "its accessibility [of the elevators] is an ESR-Essential Safety Requirement of the Lift Directive 2014".

2. EN 81:20 [35]: It complies to the ESR requirements of the Lift Directive, including accessibility. This standard is a fundamental, wide reference text for every aspect of safety requirements and protective measures of elevators.
3. EN 81:70 [36]: It is dedicated to safety rules for the independent accessibility of elevators for a wider range of persons, including passengers with disabilities. This standard—applicable according to EN 81:20—raises the elevator requirements to facilitate the use by all. The five appendices of the text are important as they further specify: general considerations on disabilities; what disabilities have been considered in the standard; a risk analysis; hypoallergenic materials; and guidelines for the visually impaired.
4. CEN/TS 81:76 [37]: It deals with technical-specific rules for the evacuation of people with disabilities and how to train persons to evacuate people with disabilities using elevators.
5. EN 81:80 [38]: It is defined as a good practice standard, not harmonized—it does not comply with the ESR requirements of the Lift Directive—but it implements the Accessibility Performance for Safe, Fair, and Healthy Recommendations 95/216 EC, giving a methodology for improving the safety of existing elevators with the aim of reaching an equivalent level of safety of a new installed elevator (elimination of cabin barriers, leveling the cabin to floors, phone call system, etc.).
6. EN 81:82 [39]: consequent to the 95/216/EC, it is dedicated to improving the accessibility of existing lifts by persons with disabilities.

By examining contexts outside of Europe, it is possible to find several references, particularly in North America, with valuable insights and perspectives on the subject matter. The non-mandatory IBC-International Building Code, in its 2018 version, advocates for the use of video communication in elevator cabins when the IBC is adopted. Similarly, the effectiveness of alternative means of communication beyond mere voice communication are also advocated in Canada and in the US by the American Society of Mechanical Engineers: ASME released in 2019 the standard A17.1-2019/CSA B44-19 [40]. The standard, however, is not mandatory across North America as it needs to be incorporated in national or local building codes. As for other countries, it should be acknowledged that the EU regulatory framework for the elevator industry is the most widely used at the international level, also in a number of non-European jurisdictions. Implementing the results of this paper in the EU standards would consequently benefit deaf passengers in other geographical areas as well.

2.4. Elevators and Deaf People: The Shortcomings in the EU Standards

Although elevator regulations are extensive and relatively advanced regarding accessibility, gaps may still be detected, in particular for certain types of disabilities. For instance, claustrophobia, which may be quite relevant for elevators, is not considered. Also, the combinations of disabilities are not considered, as it is listed in EN 81:70 [36]. Actually, these cases are not the only ones. A paradoxically overlooked issue in all standards is the behavior and condition of deaf people in cases of entrapment.

The previous version of the Lift Directive [41] prescribed the mandatory presence of an alarm device in the cabin, which must allow two-way voice communication in order to maintain a permanent connection with an emergency service. It remains unresolved how a two-way voice communication can be established for deaf individuals.

The standards do not respond to the need for one-to-one communication for deaf and hard-of-hearing people, since communication with the external operator can only be done through a telephone dialer, by voice.

The standard dedicated to the alarm system in elevators is EN 81:28 [42], and it is based on voice communication with an emergency service. This standard, harmonized with the current Lift Directive [12], introduces improvements factors of the alarm system, like visible and audible signals in the operating panel of the cabin when: (1) the alarm has been validated as a true alarm (an illuminated yellow graphical symbol); (2) the communication is ongoing (an illuminated green graphical symbol) [42], but still not enough to guarantee communication to deaf people.

Safety and accessibility are strictly linked concepts; safety in use is one of the pillars of construction safety, and it relates to how people act within buildings, spaces, and the built environment.

The updating of the technical standards is in progress, but there is a lack of evidence-based data elaborated by independent research bodies that identify the needs of the widest possible users, aimed at defining the technical requirements to provide higher accessibility and safety performances to lifts.

2.5. Advances in Technology Useful for Elevator Accessibility

As described in the previous section, contemporary elevators must ensure two-way communication in the event of entrapment and emergency. Therefore, the outgoing and incoming communication—which include the possibility to express oneself and the capability to receive messages, information, and instructions—cannot rely solely on auditory means, such as voice and hearing.

"During an emergency situation, hearing is an essential ability, [. . .] because most of the information in times of emergency is transmitted by sound in the form of verbal commands" [43–45].

The problem of emergency communication for deaf people has been known for time and various technologies are being developed and applied to bridge the gap. In the field of alarms for people with disabilities, particularly those with hearing impairments, several solutions can be mentioned: besides the visual alarm devices (quite developed within the field of fire alarm systems) [46], haptic devices [47,48], vibration-based devices [49,50], speech recognition systems [51,52]. Another interesting technology, considering the potential application in elevators, is the hearing loop in connection with the telecoil of the user [53], an assistive system able to link the sound source with the user listening device [54].

The technologies may offer several solutions; however, it is important to underline that the elevator is a means of transport for public use. Therefore, the degree of deafness of the users and/or the possible presence of hearing aids or cochlear implants by users is unknown, as is as the presence of a stable internet connection inside the building and the elevator shaft. These problems make some assistive technologies applicable only in certain cases and not in all circumstances.

The next section outlines the methodology used to collect data on the needs and requirements of deaf and hard-of-hearing people when using elevators.

3. Identification of the Needs of Deaf and Hard of Hearing Users of Elevators

3.1. Privacy and Ethical Matters

The findings of the first part of this research are based on the results of a questionnaire that involved a significant number of people with different levels of hearing loss. The methodology of the questionnaire, the storage and processing of information, and the way results are here presented have been approved by the Ethics Committee of both the Iuav University of Venice (ref. 15630 24 February 2022) and the University of Bologna (Ref. 0095498 5 April 2023)—the institutions where the researchers involved in this project operate. Respondents were informed that the study aimed to improve an aspect that is lacking in current regulations, and therefore they were encouraged to participate and share their opinions, as they view the research results as a potential enhancement of their current or future condition. The participation in the questionnaire was voluntary for all participants, exempt of remuneration, and consisted of answering questions formulated through an online questionnaire. Respondents were allowed to skip some questions and to oppose the use of their replies for the purposes of the research.

3.2. Methodology

The research consists of an exploratory statistical investigation that aims to understand how elevators can be equipped and improved to meet the needs of the widest possible range of users, with a particular focus on people with hearing disabilities.

In order to collect as much data as possible, a probability sample survey was conducted in the form of a questionnaire. The probabilistic sampling was chosen in order to reduce the sampling error of estimates for key survey variables while also minimizing the time required to conduct the survey. Various forms of surveys were explored in collaboration with ENS Veneto (Ente Nazionale Sordi/National Deaf Body). One-to-one interviews, aside from time-related issues, were excluded for several reasons: they may cause discomfort for individuals who are deaf or hard of hearing, who often prefer not to be directly questioned about their condition and may feel reluctant to participate. Furthermore, the absence of an LIS—Italian Sign Language—interpreter for translating questions and answers at all times posed another impediment. Large focus groups were also considered as an alternative; however, challenges in coordinating and gathering participants made this approach impractical. Additionally, a large number of meetings would have been required to reach the same number of participants as in the questionnaire.

The questionnaire, in turn, was chosen for its effectiveness in collecting survey data by providing organized numerical data and qualitative indications. Given the exploratory nature of the research, the respondents were also provided with some open-ended questions. These questions were designed as tools and stimuli aimed at gathering information relating to the topic. Consequently, the participants' answers can guide future research questions and help develop a more solid knowledge base for future explorations.

The questionnaire was answered anonymously, but responders interested in following the research were asked to share their email address after answering all questions. The main advantage of using the questionnaire as a data collection method is that it is a self-administered instrument, and it can be answered by a large number of participants at the same time; participants are also more willing to share sensitive information when anonymity is ensured [55].

The survey was administered to the general public, promoting it on social networks, in university classes, and through direct contacts. To attract the largest number of responses from people with hearing disabilities, the survey was promoted through associations representing deaf people in Italy throughout the national territory, with particular reference to ENS (Ente Nazionale Sordi/National Deaf Body), Fiadda (Famiglie italiane associate per la difesa dei diritti degli audiolesi/Association for the rights of deaf people and families) and APIC Torino (Associazione Portatori Impianto Cocleare/Cochlear Implant Wearers Association), contacted by email. In order to have a more widespread distribution, a message was also published on the pages of groups of people with hearing disabilities on several social networks, encouraging the completion of the questionnaire. The involvement of users who are the focus of the study was strongly pursued by the research group to gain a deep understanding of the challenges associated with using the elevator, particularly those not readily apparent to individuals without experience of disability, even if temporary. This methodological approach was recommended by the associations themselves, which actively participated in the development of the questionnaire as well as in the methods of engaging and contacting testers. The survey, prepared in Italian, has also been administered to a similarly-sized control group of individuals who identified themselves as not having hearing loss, aiming to establish a benchmark reference for each answer.

The questionnaire was initially developed based on insights gained from direct conversations with organizations representing deaf people and from some initial interviewees, both of which confirmed the research premises. Multiple versions of the questionnaire were pre-tested by ENS Veneto in a reiterative refinement of the research. The language of the questions, in fact, was found to be too complex for deaf people to read, necessitating some changes. The language was thus made simpler and more concise, and the questionnaire was accompanied by an explanatory video in LIS (Italian Sign Language), produced by

ENS Veneto. This video in LIS language was available at the beginning of the questionnaire and was also used on social media networks to encourage participation. From the point of view of language and communication, in fact, deaf subjects represent a heterogeneous group [56].

3.3. Sample

The sample included 287 participants with deafness and hearing loss and 218 participants without hearing loss. The deaf and hard of hearing group was composed of 178 females and 106 males (3 preferred not to answer). The group without hearing loss was composed of 126 females and 88 males (4 preferred not to answer). The age distribution for both groups is presented in Figure 1. The hearing loss was acquired in 25.56% of cases and from birth in 74.44% of cases. Hearing supports were distributed in 44.57% with hearing aids, 26.66% with cochlear implants, and 28.77% without hearing support, as graphically represented in Figure 2.

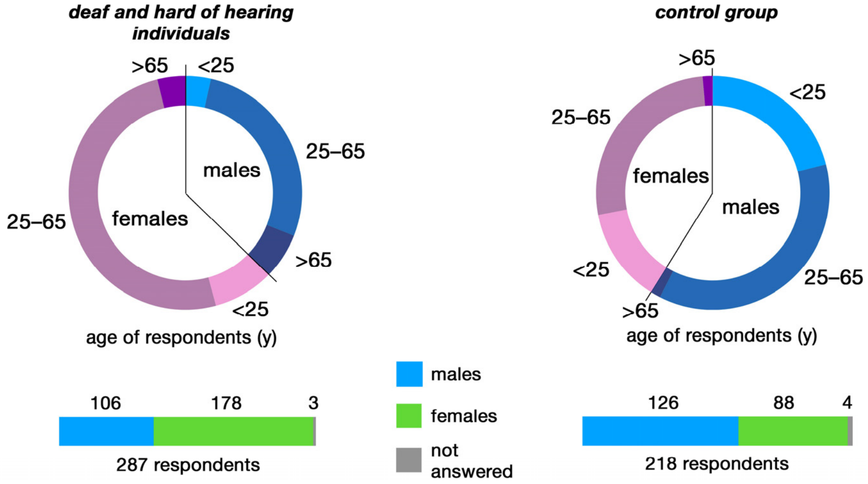

Figure 1. Socio-demographic respondents' profile.

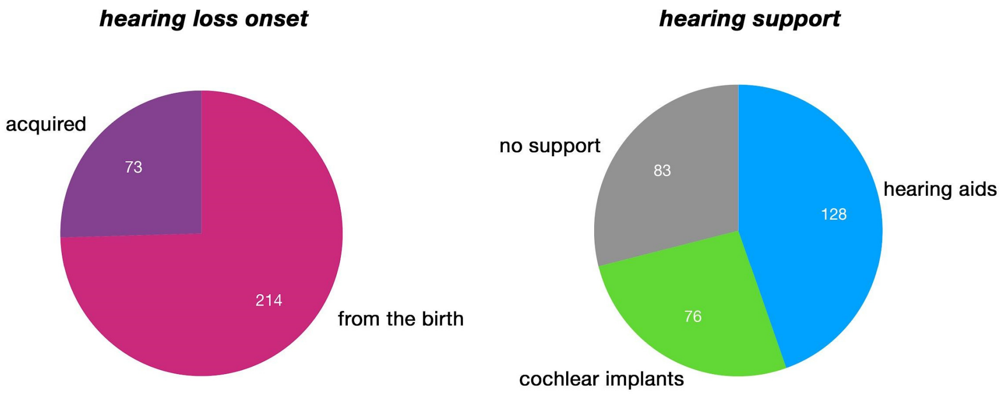

Figure 2. Typologies of hearing loss and used support.

3.4. Structure of the Questionnaire

The questionnaire consisted of 27 questions organized into three sections. In the first section, questions investigated personal information of the respondent in which, while preserving the participants' anonymity, the traditional data relating to gender, region of origin, and age was acquired. Furthermore, questions in the first section of the survey asked about the type of deafness (congenital or acquired subsequently) and any remedies adopted to compensate for the deafness (such as a cochlear implant, hearing aid, or the absence of remedies). These last two types of questions were aimed at deepening the analysis, as the timing of when the disability manifested itself can impact the acquisition and understanding of language [57]. Furthermore, the aid employed to address the disability condition may influence the user's attitude towards the surrounding space, as indicated by some interviewees.

In the second section of the questionnaire, questions were aimed at understanding the respondents ease of use and identification of elevators within buildings and questions about the perceived safety in the use of elevators.

In the third section, the respondents to the questionnaire were presented with information regarding the characteristics and physical dimensions of elevator cabins. They were then asked about any preferences for modifications, trying to understand what design changes could be implemented to make elevators more usable for people with hearing disabilities. Additionally, respondents had the opportunity to specify any additional instruments or physical-technical characteristics they consider essential for the correct and safe use of the lifts.

The most relevant questions that have been used to develop the results presented in this paper are described below.

Gender and age (<25, 25–65, >65) were recorded as socio-demographic data.

Specific questions investigating elevator-user experience were:

(1) According to your experience, how would you rate the ease of use of elevators? (4-point Likert scale);
(2) Have you ever found difficulties in the use of elevators? (Yes/No);
(3) If yes, please specify the difficulty that you have found (open question);
(4) In general, how would you rate the safety level of using elevators? (4-point Likert scale);
(5) Are there elevator features that you associate with fear? (open question);
(6) Have you ever needed an accompanying person to use an elevator? (Yes/No);
(7) If you are alone, do you avoid taking elevators? (Yes/No);
(8) Have you ever been stuck in an elevator (also temporarily)? (Yes/No);
(9) Would you prefer elevators with transparent walls? (Yes/No);
(10) Would you consider it useful to have the possibility to make video calls or text messages to an operator in case of emergency? (Yes/No).

Only for participants with hearing loss, the questionnaire included also the following questions:

(1) Was the hearing loss from birth or was it acquired at a later stage? (Birth/Later);
(2) Do you use hearing devices to try to compensate for the hearing loss? (No/Hearing aid/Cochlear implant).

Answers were processed, and data were analyzed using statistical parameters. The results of this activity are presented in the next section, "4. Data Analysis and Results".

3.5. Limitations of the Study

The authors acknowledge that, beyond the accuracy of responses to general questions regarding age, gender, etc., answers related to the specific field of elevator use may be subject to bias. This bias may arise because respondents report their perceptions based on personal experience, which may be slightly exacerbated by their own direct involvement. Another limitation is the potential for respondents to have multiple disabilities, beyond hearing loss, which could further affect their ability to use the elevators.

4. Data Analysis and Results

The questions with Likert four-point scales (used in place of a traditional five-point one in order to avoid the neutral answer) regarding the ease of use and safety perception of using the elevator were analyzed using an analysis of variance (ANOVA), with group (2 levels: deaf and hard of hearing, control) as the independent variable. Questions with categorical responses were analyzed with the Chi-square test to examine whether the two responses are independent in influencing the test statistic. The effect size was computed as eta squared (η^2—which represents the proportion of the total variance that is attributable to the group differences) for ANOVA tests and phi (φ—which measures the strength of the association between the variables) for Chi-square tests.

4.1. Self-Perceived Ease of Use (Question #1)

The ANOVA showed a significant difference for the two groups: the test statistic F (1 between-group degrees of freedom, 502 within-group degrees of freedom) reported 80.57, with a quite insignificant $p < 0.001$ (probability of obtaining the observed results if there were no actual difference between the groups) and an effect size of $\eta^2 = 0.14$. The mean rating was 3.71 (standard deviation SD = 0.61) in the control group and 2.97 (SD = 1.09) in the deaf and hard of hearing group. The scale was from 1 (very difficult) to 4 (very easy), and the results of the questions are graphically represented in Figure 3.

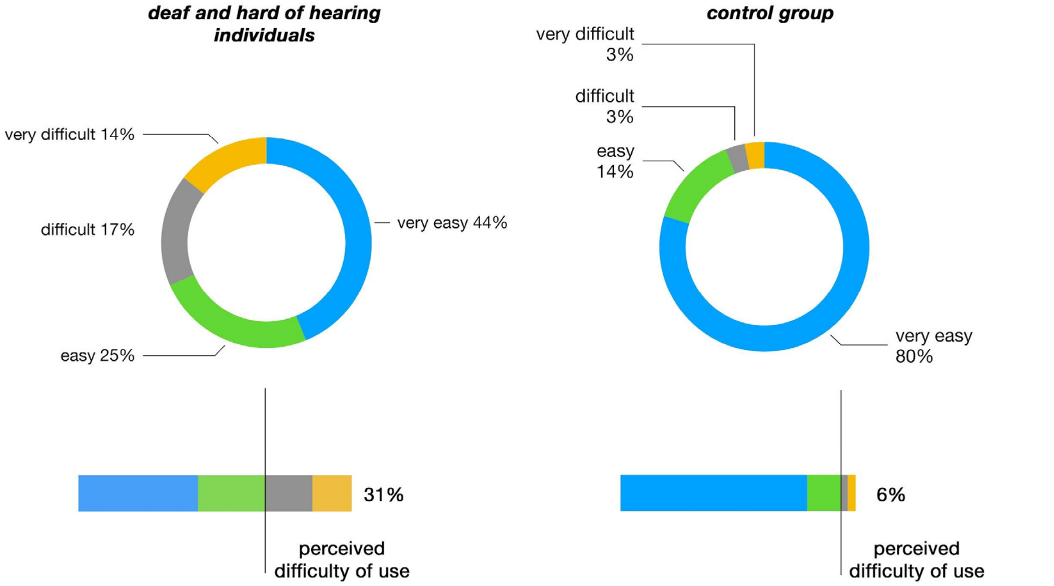

Figure 3. Self-perceived level of difficulty while using the elevator reported by the two samples.

The ease of using the elevator significantly decreases with age in the deaf and hard of hearing group, as shown in Figure 4. This represents a significant barrier for deaf people when using elevators. Regarding the ease of finding the elevators, which is directly related to their clear indication in the building, half of the younger people (under 25) find it easy, whereas around 61% of both the 25–65 age group and those over 65 find it difficult to locate the elevator.

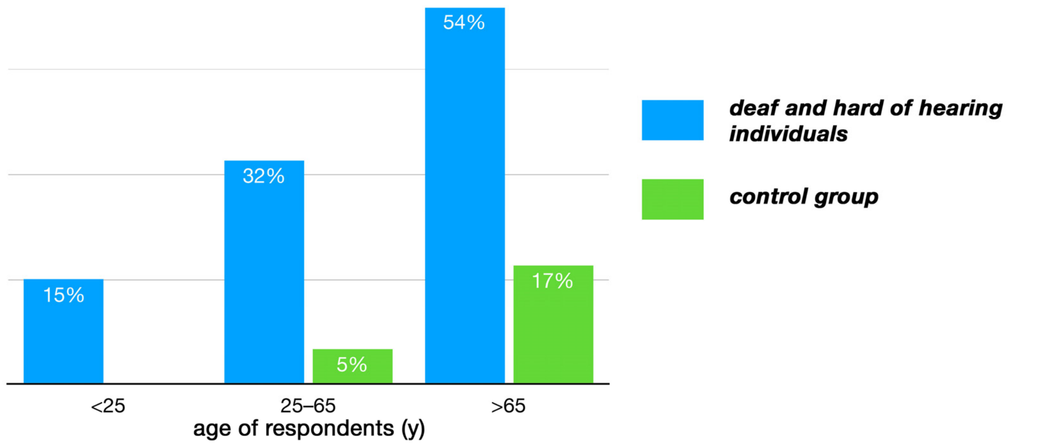

Figure 4. Share of respondents who face difficulties in using elevators, divided by groups and ages.

4.2. Difficulty in the Use of Elevators (Questions #2 and #3)

The proportion of participants who declared difficult experiences in the use of elevators was 12.90% in the control group and 37.97% in the deaf and hard of hearing group. The Chi-Square test applied to the contingency table shows a significant association between hearing loss and experiencing difficulties with elevators: $\chi^2 = 37.99$ (measuring the difference between the observed frequencies and the expected frequencies), $p < 0.001$, $\varphi = 1.69$, which means there is a strong association between hearing loss and the experience of difficulty using elevators.

The difficulties that were declared in the open question by participants could be classified into five main categories: malfunctioning of the elevator, small size of the cabin, claustrophobic experience (including the lack of windows and transparent surfaces), problems of communication during an emergency, and the difficulty of mapping the floor numbers in the elevator button panel with the position of each floor. The hierarchical distribution of how the two groups responded to this question varies remarkably, as it can be noted in Figure 5.

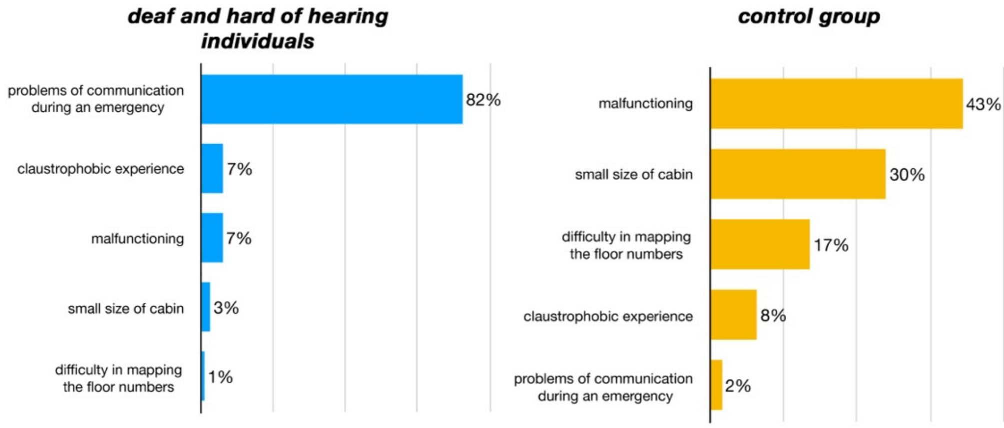

Figure 5. Problems in using elevators declared by the two samples.

4.3. Self-Perceived Safety Level (Questions #4 and #5)

The ANOVA showed a significant difference between groups: $F(1, 502) = 48.97$, $p < 0.001$, $\eta^2 = 0.08$. The control group reported a higher mean safety level compared to the deaf and hard of hearing group. In fact, the mean self-perceived safety level rating was 3.01 (SD = 0.70) in the control group and 2.46 (SD = 0.97) in the deaf and hard of hearing group. The scale was from 1 (very low) to 4 (very high). While only 13% of the control group found the use of elevators unsafe, as many as 47% of the deaf and hard of hearing group did (Figure 1); most of the reasons for this feeling of unsafety were connected to the possibility of being stuck during an emergency stop and the inability to communicate with the outside. Results are visually represented in Figure 6.

4.4. Avoidance of Using the Elevator Alone (Question #6 and #7)

The percentage of participants who declared to avoid using the elevator alone was 37.28% in the deaf and hard of hearing group and 28.57% in the control group. The Chi-Square test ($\chi^2 = 3.82$) results suggest that there is a trend towards a statistically significant difference between the deaf and hard of hearing group and the control group in terms of avoiding using the elevator alone. Although the difference is not strongly significant ($p = 0.05$), the effect size ($\varphi = 0.17$) indicates a small to moderate association between group membership (deaf and hard of hearing vs. control) and the behavior of avoiding using the elevator alone. This means that participants with hearing loss are somewhat more likely to avoid using the elevator alone compared to those in the control group. This confirms that many deaf people do not use elevators, which is anecdotal evidence that sparked the idea for this research. Specifically, the reason for avoiding the elevators among the deaf and hard of hearing respondents is that stairs represent a safer environment for people over 65 years old and offer a fitness opportunity for those under 25 years of age. In addition, 21% of the deaf and hard of hearing sample reported the need to be accompanied when using the elevator, indicating that without help, they would not have used it. Data is visually represented in Figure 7.

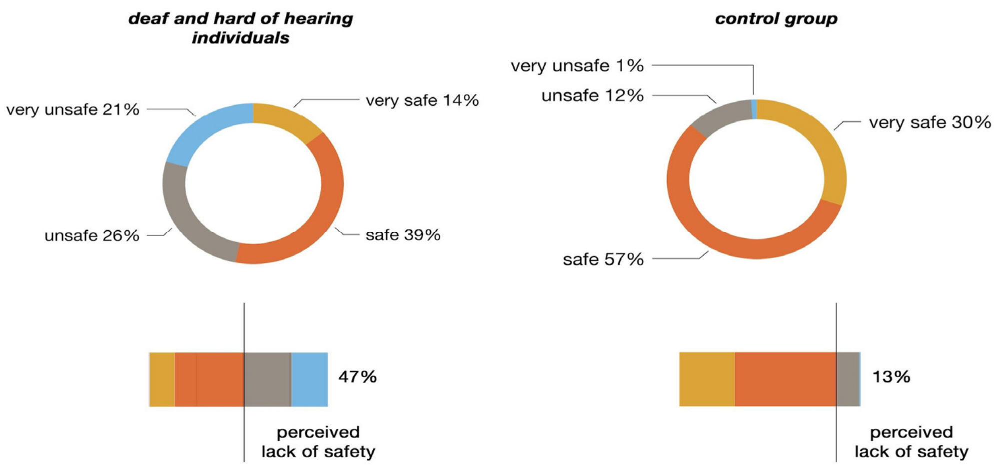

Figure 6. Self-perceived level of safety while using the elevator, as reported by the two samples.

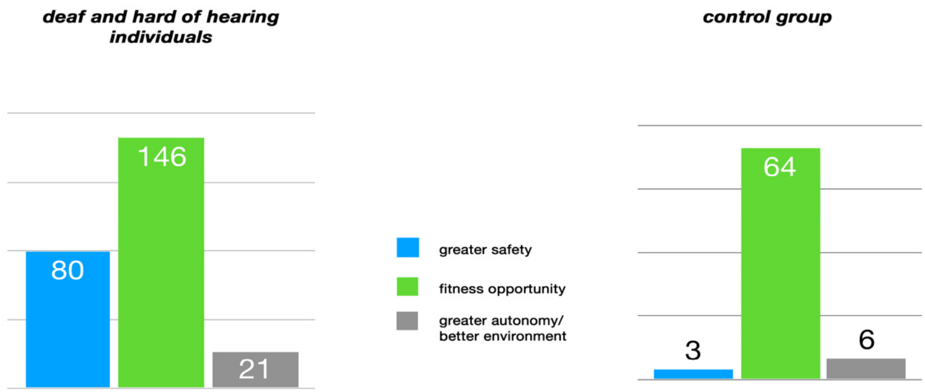

Figure 7. Reasons for avoiding the use of elevators, reported by the two samples.

4.5. Experience of Being Trapped in an Elevator (Question #8)

The experience of being stuck in an elevator was declared by 54.70% of participants in the deaf and hard of hearing group and 47.92% of participants in the control group. The difference between the two groups was not significant ($p = 0.15$). This is a confirmation of the validity of the responses received since the likelihood of being trapped in an elevator is not influenced by the hearing capacity or any other characteristics of the passenger. Still, in both cases the frequency of entrapments is quite high, suggesting that maybe the meaning of the question was misunderstood by the responders.

4.6. Preference for Transparent Walls (Question #9)

The preference for transparent walls in the elevator cabin was expressed by 72.72% of participants in the deaf and hard of hearing group and only 33.78% of participants in the control group (Figure 8). The Chi-Square test confirmed that this difference is statistically significant ($\chi^2 = 60.27$, $p < 0.001$), with a very strong association between hearing loss and the preference for transparent walls ($\varphi = 2.68$). It can be stated that while for deaf and hard of hearing participants, using cabins with transparent walls can be helpful for communication with the outside and can provide relief regarding safety, transparency can decrease the sense of privacy and potentially increase vertigo for the control group. Some discrepancies can also be found within the group of deaf and hard-of-hearing participants. Interestingly, all respondents over 65 years of age declared a preference for transparent walls, while this preference decreased to 73% for participants aged 25–65.

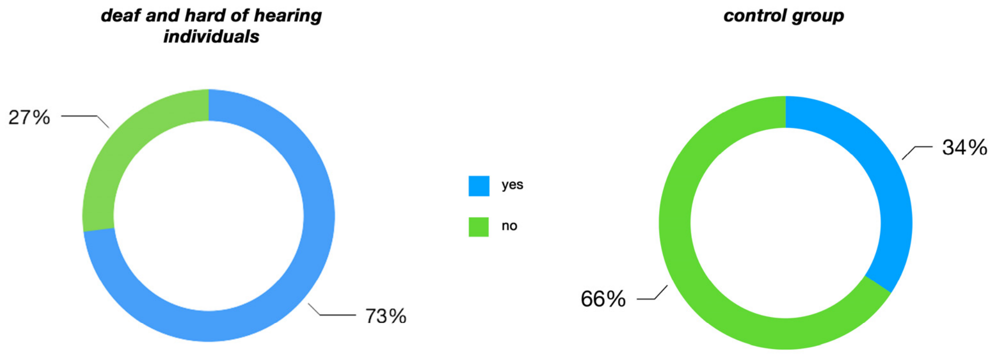

Figure 8. Preference for transparent walls as reported by the two samples.

4.7. Availability of Video Calls and Texting to the Emergency Operator During an Emergency (Question #10)

The availability of video calls and/or the possibility of texting during an emergency was evaluated very differently by participants in the two groups, as shown in Figure 9. The Chi-Square test confirmed this difference as statistically significant (χ^2 = 131.75, $p < 0.001$) with a very strong association between deafness and hearing loss and the preference for these communication options in emergencies (φ = 5.86). For the control group, the traditional emergency call remains a good way to communicate with the outside, and only 3% of the participants suggested text messaging as a possibility.

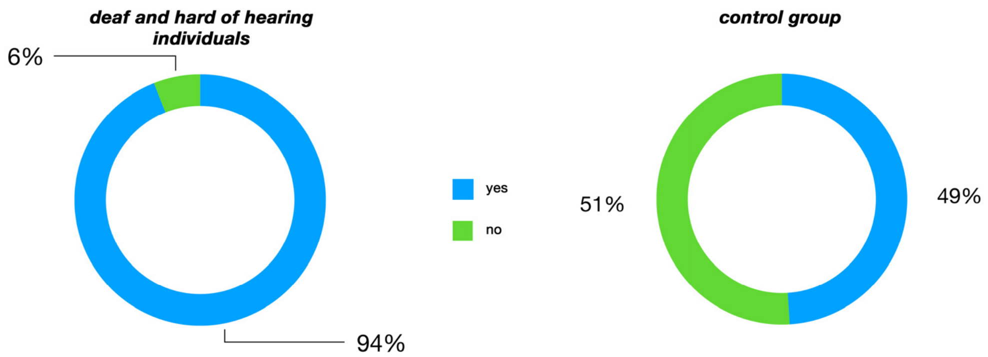

Figure 9. Preference for video call or texting during an emergency, as reported by the two samples.

4.8. Considerations and Suggestions for Improving Elevators Safety (Question #11)

Among the 176 responses given to question 11, which was not mandatory, more than half of the deaf and hard of hearing sample (52%) reported video, display, or video call as features to add to elevators. The second most reported topic was the possibility to communicate with someone outside the cabin, which, if combined with the possibility of sending text messages, accounts for 28% of the responses. Less reported were preferences for transparent walls for cabins, a light signal for notifying the arrival at the floor, and the possibility of communicating with someone using sign language (the last suggestion was usually combined with the video feature) (Figure 10).

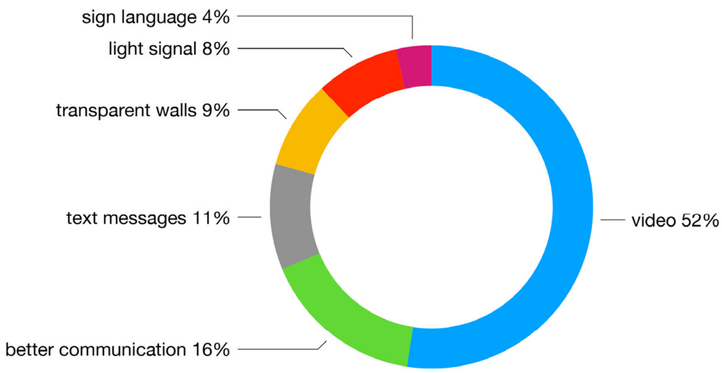

Figure 10. Results of the open-ended question regarding preferences of users.

5. Discussion and Verification of the Results

Building on the data analysis, this section aims to present the key results and findings identified during the study. The insights gathered are crucial to understanding the challenges faced by deaf people when interacting with elevators. These findings will serve as the basis for recommendations and further research aimed at improving elevator accessibility and safety.

5.1. Analysis of the Results of the Questionnaire

The results of the questionnaire clearly show that the self-perceived safety and usability of elevators are significantly lower in the deaf and hard of hearing group.

A higher proportion of participants in this group declared to avoid using the elevator alone and declared to have experienced problematic situations when using elevators. This is a serious limitation of their willingness and ability to move across different floors and can be a source of social segregation, especially in dense cities where multi story buildings are predominant.

Specifically, they showed a strong request (81.55%) to introduce an interface that would allow visual/textual communication with the operator during an emergency call, overcoming the actual limitations of communication based only on the audio channel.

Elevator shafts are usually built in reinforced concrete. In multi-story buildings, this vertical concrete element serves as the main bracing element for the entire building, the one that resists the horizontal forces caused by wind and moderate earthquakes. Consequently, cell phones, which could provide an alternative means to communicate in case of emergency, may not work; from here, the need to rely on the emergency communication system built into the elevator.

Because of the impossibility of establishing communication in case of emergency, a higher proportion of participants with hearing deficits reported avoiding the use of an elevator alone (37.28% vs. 28.57% in the control group) and reported a preference for elevators with transparent cabin walls and transparent shaft walls (72.72% vs. 37.78% in the control group). This preference could probably be explained considering that an elevator with transparent surfaces would allow a deaf or hard-of-hearing person to better communicate with the exterior in case of an emergency, increasing the perception of safety and confidence. In addition, transparent surfaces in the cabin could mitigate the perception of closure and confined space, reducing claustrophobic experiences. From a constructive perspective, this can be achieved with the substitution of the concrete shaft with a steel one and transferring the wind and seismic bracing capabilities of the elevator shaft to another element of the building structure.

Looking at specific characteristics, respondents with hearing loss or deafness from birth generally experience more difficulties using an elevator compared to those who developed hearing loss or deafness later in life (45% vs. 35%). The former also feel less safe (54% vs. 38%). This evidences that the user develops a familiarity with the use of elevators that remains even after hearing loss or deafness develops. Respondents with cochlear implants are more likely to use the elevator to move in a building, as they report a generally higher sense of safety (75%) compared to those wearing hearing aids (47%) and, understandably, those using no devices (40%).

In the control group, the difficulties that were reported were more polarized on malfunctioning, the small size of the cabin and claustrophobic experiences, and the difficulty of matching floor numbers with the exact destination.

Some interesting remarks arise from questions regarding the physical features of the elevators. Their effectiveness is high as the responses come from a numerically large group of people, evidencing a very different perception of the environment between people that can rely on all five senses and those that must rely on other senses to compensate for a complete or partial loss of their hearing capacity. This impacts predominantly on sight, and hence different desired levels of lighting inside the elevator cabin. In fact, more than half of the deaf and hard of hearing respondents (54%) would increase the internal light of the cabin, while only 39& of the control group would. Despite there being no literature evidence on the preference for increased indoor lighting needs in deaf people, the request for a more illuminated cabin may be connected with the need to compensate with sight information not coming from sounds.

Most of the respondents from both the deaf and hard of hearing and control groups preferred a larger cabin access (around 80%). While 20% of the group with hearing problems would increase the speed of the cabin, the share increases up to 38% in those without any hearing loss, marking a significant difference. This is likely due to the problems of balance encountered by many deaf people as a side effect of their disability [58,59].

The results of the research could influence other building interfaces. For example, cord-operated emergency alarm systems, which are mandatory in Italian bathrooms, and domestic fire alarms, which are currently only sound-operated, would benefit from additional features such as visual signals to alert individuals with hearing loss. Additionally, in trains, at toll booths, and at emergency call stations along highways, implementing a video communication system with text input for emergency situations could replace the current voice-only system.

5.2. Testing Procedure to Validate the Results

Building on the results of the questionnaire, the next step of the research consisted of testing an alternative emergency call design that would overcome the impossibility for people with hearing disabilities to communicate with the emergency operator.

A group of 80 participants, including 33 with hearing loss or deafness and 47 who identified as having no hearing loss (mean age = 32.56 years, SD = 10.80), was invited to participate in a test conducted within the Environmental Psychology Lab of the University of Bologna.

After testing the participants' hearing level via a pure-tone audiometry test and their level of oral communication with a Likert scale test administered by the tester, participants were conducted to the test facility. The test facility consisted of a stationary elevator cabin specifically adapted for this experiment. The possibility to use a real elevator was ruled out immediately because the modification that the test required would have changed the safety equipment of the cabin, making it not compliant with the mandatory prescriptions for passenger elevators.

Several options to enhance the communication capabilities of deaf and hard of hearing users have been considered; ultimately, it was decided to add a text-based communication channel to the norm-compliant audio channel to communicate with the operator in case of emergency.

A commercially available cabin was transported in disassembled parts and then assembled on-site in Bologna (Figure 11). The structure of the cabin, made up of steel elements, was located in the entrance hall of the laboratory, featuring external dimensions of 1200 × 1680 mm (Figure 12). The cabin used for the test is the "CosyTime" model (NOVA

Elevators); its free floor measures 1090 × 1400 mm and it's furnished with stainless steel panels covered by a textile fabric. The access door provides a passage of 900 × 2000 mm.

Figure 11. Assembly of the cabin inside the Environmental Psychology Lab of the University of Bologna.

Figure 12. The cabin installed inside the Environmental Psychology Lab of the University of Bologna.

Despite its inability to move, the cabin was connected to electricity, and its door-opening and internal lighting features were fully operational to simulate as much as possible a real elevator. The cabin was modified for the experiment with several features (Figures 3 and 4): a push switch replaced the calling button, serving as an emergency opening command from the outside; the internal display was removed to make room for a wider screen where instructions were issued to participants; and a video camera with a microphone was installed to allow participants to communicate with the control desk and for the tester to record any movements inside the cabin.

The test asked participants to behave as they would in a normal elevator cabin and to follow instructions issued on the screen. It is important to note that users were not informed of the purpose of the test and did not know what specific aspect of their interaction with the elevator was being monitored. During the test, an emergency stop was simulated and the reactions recorded. The code-compliant emergency-call system was compared to a system that included an audio–video call and the possibility of a bidirectional textual communication of the user with the emergency operator. In both cases, the emergency call was classified as successful if the participant was able to understand the instructions given by the tester and to spell or to text its name and surname.

Looking at the results of the experiment, it can be noted that the emergency call failed for 85% of the participants in the traditional settings. The failures were mostly due to difficulties experienced in communicating through the audio system, but also due to the lack of understanding of the procedure to initiate the emergency call. Specifically, only 35% of participants succeeded in initiating the alarm call with a single button press. In the remaining 65% of cases, multiple presses were required: twice in 29%, three times in 23%, four times in 6%, and five or six times in 3% each. In four cases (12%), participants were unable to issue the alarm call because the button was not pressed for at least three seconds within two minutes. In these instances, the button was pressed 2, 2, 9, and 14 times, but none of these presses lasted the required duration. In the remaining cases, participants successfully issued the alarm call, with a mean number of presses of 2.21 (SD = 1.65) in the control group and 2.41 (SD = 1.31) in the deaf and hard of hearing group.

In contrast, when using the experimental settings, 100% of the participants, from both the deaf and hard of hearing and control groups, succeeded.

This highlights the urgent need to revise the standards integrating cabins with audio-visual means of communication, with the aim of better addressing deaf and hard-of-hearing people's needs.

It is interesting to note that, despite the cabin being unable to move, several users with deafness or hearing loss were extremely reluctant to enter the cabin and start the experiment for fear of being trapped with no external communication.

6. Conclusions

The present research stems from an anecdotal observation from the authors on the avoidance of the use of elevators by deaf and hard-of-hearing people. The objective is to empirically verify this circumstance by using a questionnaire to measure the perceived problems and preferences of deaf and hard of hearing users and comparing the results with a control group of people without hearing impairments. The results of the questionnaire are verified with an experiment that involves the two groups, simulating an emergency call.

The large number of completed questionnaires (287 participants with deafness or hearing loss and 218 participants having no hearing loss) ensures objective evidence of these findings, useful for the elevator industry and regulatory/legislative bodies in the context of evolving elevators to provide greater autonomy, safety, and comfort to the widest possible range of users, including those with disabilities, particularly deafness and hearing loss.

Three major trends substantiate the relevance of the research presented here. Firstly, the ongoing global trend of urbanization predicts the growth of urban populations and the construction of more multi-story buildings. Secondly, the presence of an existing stock of elevators that are not yet compliant with the needs of persons with various disabilities, including deaf people. Lastly, the increase in population longevity leads to a higher prevalence of age-related disabilities, including deafness and hearing loss, in an increasingly large population.

6.1. Impact of the Research on Regulatory/Legislative Bodies and on Elevator Industry

An important aspect of this paper is that it quantitatively and qualitatively identifies the needs of a specific category of users of elevators, and it also measures, with a test, the anticipated improvements. The EU standards on the accessibility of lifts in many cases, as pointed out in Section 2.3, are not comprehensive of all the types of disabilities, not even of the most statistically frequent ones. When a disability is mentioned, there is no evidence in the literature of data, tests, or other measurable ways upon which the prescriptions of the norms have been created. More in general, the present research advocates for a comprehensive study on, at least, the most statistically frequent disabilities. Such exploration shall be done by way of a direct interaction with the specific users, their families and the associations that represent them, leading to verifiable data and measurable parameters.

As mentioned in Section 2.4, the main gap regarding the accessibility of elevators for deaf individuals concerns the alarm system, which does not meet the requirement for one-to-one communication, as it relies on a telephone dialer and voice communication. This gap is evidently insurmountable for a deaf person. In fact, the questionnaire reveals the awareness of communicative isolation in case of entrapment, as expressed by the deaf and hard of hearing respondents. The results of the questionnaire emphasize the need to provide one or more multi-sensory and multi-channel communication systems within the elevator cabin to enable deaf individuals to both express themselves and receive information. Most importantly, the third-party services that respond to emergency calls should be able to provide the type of service required by deaf users, such as sign-language-capable operators.

The industry of elevators already offers technological advances that are significantly ahead of the norm requirements. LED screens are often added in elevator cabins to inform passengers on building-related news, weather forecasts, or other infotainment announcements. In some countries—particularly in the US, in response to the ASME norms—products that offer video connectivity for emergency calls are already available. Given the availability of such products, the elevator industry itself should promptly take the lead in raising the standards of elevator accessibility. Even if the regulatory framework is still lacking, it is crucial to ensure such products are provided as a default in new installations, even in non-premium elevator cabins and major retrofits.

From the industry perspective, while products for the visual communication in elevator cabins are already available on the market, a crucial issue remains: the limited capacity of emergency call operators to provide video communication, let alone LIS support. For building owners and managers, in turn, one of the major implications is the additional cost for the data connection required to support the video communication system, which would particularly affect small condominiums or holiday homes.

Lastly, it's important to highlight significant problems related to the applicability of standards for ensuring the safety of elevator systems. These include, as mentioned in Section 2.2, the great number of standards that are sometimes conflicting with each other and the consequent uncertainty in their adoption by the industry and professionals in the field. The same actors also tend to apply the lowest level of requirements specified in the standards for cost reasons or a conservative behavior.

6.2. Future Research

The results of the research conducted highlight the need for further investigation into the specific needs of persons with disabilities. This will provide legislators and manufacturers with reliable data to inform the development of new, more inclusive products. Accessibility is a universal value inherent right that benefits everyone. Deaf or hard of hearing individuals should be able to participate in public life and access public spaces with the highest possible level of freedom, equal to that of people with other disabilities or without disabilities.

The research presented in this paper evidences two necessities for the safe evolution of elevators in terms of maximum utility:

1. Ensuring the broadest possible analysis of the needs of individuals with disabilities, which means conducting extensive investigation campaigns with disabled individuals, their families, caregivers, and specialized personnel. These collective efforts are capable of highlighting the complexity and breadth of needs and constraints that must be considered. A thorough needs assessment is essential for developing effective technical solutions that address the real challenges faced by deaf and hard of

hearing individuals, instead of assuming knowledge on the part of those who do not experience accessibility issues in their daily lives.
2. Actively engaging in regulatory updates with substantial will and organization, bearing in mind that regulations cannot address accessibility in a piecemeal fashion but must be approached comprehensively. The research highlighted, in fact, an industry-wide need for further research on the topic. A very important unexplored area involves the conduction of tests on the behavior of additional types of disabilities during the interaction between the human being and the elevator. The categories of users could involve the most frequent types of disabilities or specific disabilities related to specific buildings. For instance, to identify the specific needs of senior users to be applied in elderly nurseries. Additionally, it has to be acknowledged that some disabilities are often combined in one single individual.

Deaf people are usually defined as the "invisible disabled", i.e., not immediately or easily recognizable by the population. For this reason, awareness of the needs of deaf people should be stimulated in hearing people, explaining the essential role of an accessible and inclusive public space for the creation of a more equal, productive, civil, and safe society. Considering that the United Nations, through the "Convention on the Rights of Persons with Disabilities", identifies environmental accessibility as a means to prevent discrimination, it is imperative for the elevator industry to comprehensively include as many types of disabilities as possible.

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References

1. United Nations, Department of Economic and Social Affairs, Population Division (2018). The World's Cities in 2018—Data Booklet (ST/ESA/SER.A/417). Available online: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/Jan/un_2018_worldcities_databooklet.pdf (accessed on 17 July 2024).
2. United Nations. *The Sustainable Development Goals Report 2024*; United Nation Publications: New York, NY, USA, 2024.
3. Levasseur, M.; Desrosiers, J.; Whiteneck, G. Accomplishment level and satisfaction with social participation of older adults: Association with quality of life and best correlates. *Qual. Life Res.* **2010**, *19*, 665–675. [CrossRef] [PubMed]
4. Steinfeld, E.; Maisel, J. *Universal Design: Creating Inclusive Environments*; Wiley: Hoboken, NJ, USA, 2012; p. 400.
5. United Nations-UN. Convention on the Rights of Persons with Disabilities–CRPD. § Article 3—General Principles. Available online: https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd (accessed on 19 August 2024).
6. Ma, S.; Li, T.; Yang, Y. Housing Price Appreciation Effects of Elevator Installation in Old Residential Areas: Empirical Evidence Based on a Multiperiod DID Model. *Adv. Civ. Eng.* **2022**, *2022*, 1–10. [CrossRef]
7. Jacob Smith, S. The American Elevator Explains Why Housing Costs Have Skyrocketed. *The New York Times*, 8 July 2024.
8. Petucco, D.; Trabucco, D. L'ascensore in architettura/The lift in architecture. *Elevatori* **2013**, *42*, 46–52.
9. Trabucco, D.; Giacomello, E.; Alberti, F. L'ascensore in architettura. Progettazione, dimensionamento, normativa e casi studio/The elevator in architecture. In *Design*, *Dimensioning, Standards and Case Studies*; Franco Angeli: Milano, Italy, 2018; pp. 1–289.

10. Trabucco, D.; Belmonte, M.; Schöllkopf, K.O. *Ropeless Elevator Systems: The Potential for Multidirectional Transportation in Tall Buildings*; Council on Tall Buildings and Urban Habitat: Chicago, IL, USA, 2019; ISBN 9780939493661.
11. Giacomello, E.; Milocco Borlini, M.; Pavan, D.; Conti, C.; Trabucco, D. Accessibility performance for a safe, fair, and healthy use of the elevator. In Proceedings of the IEA–International Ergonomics Association 21st Triennal Congress, Vancouver, BC, Canada, 13–18 June 2021; Black, N.L., Neumann, W.P., Noy, I., Eds.; Springer: Cham, Switzerland, 2021; pp. 255–262.
12. Directive 2014/33/EU of the European Parliament and of the Council of 26 February 2014 on the Harmonisation of the Laws of the Member States Relating to Lifts and Safety Components for Lifts. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0033 (accessed on 16 September 2024).
13. Kukhnin, A. Global Elevators and Escalators, Elevator World, 1 February 2022. Available online: https://elevatorworld.com/article/global-elevators-escalators/ (accessed on 16 September 2024).
14. Anie/Assoascensori, Dati di Settore di Ascensori e Scale Mobili (Restricted Access). 2022. Available online: https://assoascensori.anie.it/settore-in-cifre/ (accessed on 14 June 2024).
15. Decreto del Ministro dei Lavori Pubblici 14 Giugno 1989, n.236. Prescrizioni Tecniche Necessarie a Garantire L'accessibilità, L'adattabilità e la Visitabilità Degli Edifici Privati e di Edilizia Residenziale Pubblica, ai fini del Superamento e Dell'eliminazione Delle Barriere Architettoniche [tr. Technical Requirements Necessary to Guarantee the Accessibility, Adaptability and Visitability of Private Buildings and Public Residential Buildings, for the Purpose of Overcoming and Eliminating Architectural Barriers]. Available online: https://www.gazzettaufficiale.it/eli/id/1989/06/23/089G0298/sg (accessed on 28 March 2024).
16. Gintux. 2023. Available online: https://gitnux.org/elevator-accident-statistics/#:~:text=How%20many%20fatalities%20are%20reported,or%20passengers%20performing%20unsafe%20activities (accessed on 28 March 2024).
17. CPWR. 2013. Available online: https://www.cpwr.com/wp-content/uploads/publications/elevator_escalator_BLSapproved_1.pdf (accessed on 28 March 2024).
18. US Department of Labor. Occupational Safety and Health Administration. Available online: https://www.osha.gov/fatalities#&sort[#incSum]=0-1-1-0 (accessed on 5 August 2024).
19. Anie/Assoascensori, Dati di Settore di Ascensori e Scale Mobili (Restricted Access). 2024. Available online: https://assoascensori.anie.it/settore-in-cifre/ (accessed on 14 June 2024).
20. Bechis, C.; Cuscito, E. Fasano, Muore nel Vano Ascensore: 25enne Precipita dal Quarto Piano di un Palazzo. *Corriere del Mezzogiorno*, 1 July 2024.
21. WHO. *International Classification of Functioning, Disabilities and Health: ICF*; WHO: Geneva, Switzerland, 2001.
22. Kazou, K. Analysing the Definition of Disability in the UN Convention on the Rights of Persons with Disabilities: Is it really based on a 'Social Model' approach? *Int. J. Ment. Health Capacit. Law* **2017**, *23*, 25–48. [CrossRef]
23. Chan, F. The World Health Organization ICF Model as a Conceptual Framework of Disability. In *Understanding Psychosocial Adjustment to Chronic Illness and Disability: A Handbook for Evidence-Based Practitioners in Rehabilitation*; Springer: Berlin/Heidelberg, Germany, 2009; pp. 24,26.
24. Erkiliç, M. Conceptual challenges between Universal Design and disability in relation to the body, impairment, and the environment. *METU J. Fac. Archit.* **2011**, *28*, 181–203. [CrossRef]
25. WHO—World Health Organization-Regional Office for Europe. Disability. Factsheets. Sustainable Development Goals. (p.1). Available online: https://www.euro.who.int/en/SDG-health-fact-sheets (accessed on 16 September 2024).
26. United Nations. Implementation of the World Programme of Action Concerning Disabled Persons Report of the Secretary-General A/49/435. Available online: https://www.un.org/esa/socdev/enable/arep49_435e2.htm (accessed on 16 September 2024).
27. United Nations-UN. World Programme of Action Concerning Disabled Persons, (A/37/351/Add.1 andAdd.1/Corr.1, annex). 2013. Available online: https://www.un.org/development/desa/disabilities/third-quinquennial-review-and-appraisal-of-the-world-programme-of-action-concerning-disabled-persons-a52351-part-1-of-2.html (accessed on 20 August 2024).
28. Rathee, G.; Garg, S.; Kaddoum, G.; Alzalin, S.; Gumaei, A.; Hassan, M. Accessibility and ensured quality of life for disabled people using trusted edge computing. *Alex. Eng. J.* **2023**, *82*. [CrossRef]
29. United Nations-UN. Accessibility and Development: Environmental Accessibility and Its Implications for Inclusive, Sustainable and Equitable Development for All. 2013. Available online: www.un.org/disabilities/documents/accessibility_and_development_june2013.pdf (accessed on 15 February 2024).
30. *ISO 21542:2021*; Building Construction—Accessibility and Usability of the Built Environment. International Organization for Standardization: Geneva, Switzerland, 2021.
31. *EN 17161:2019*; Design for All—Accessibility Following a Design for All Approach in Products, Goods and Services—Extending the Range of Users.
32. *EN 17210:2021*; Accessibility and Usability of the Built Environment—Functional Requirements.
33. Conti, C. Accessibilità ambientale [tr. Environmental accessibility]. In *Manifesto Lessicale per l'accessibilità Ambientale [tr. Lexical Manifesto for Environmental Accessibility]*; Baratta, A.F.L., Conti, C., Tatano, V., Eds.; Anteferma Edizioni: Conegliano, Italy, 2023; p. 40.
34. Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and Amending Directive 95/16/EC (Recast). Available online: https://eur-lex.europa.eu/eli/dir/2006/42/2009-08-07 (accessed on 16 September 2024).
35. *EN 81–20:2020*; Safety Rules for the Construction and Installation of Lifts—Lifts for the Transport of Persons and Goods Part 20: Passenger and Goods Passenger Lifts.

36. *EN 81–70:2021*; Safety Rules for the Construction and Installation of Lifts—Particular Applications for Passenger and Goods Passenger Lift—Part 70: Accessibility to Lifts for Persons Including Persons with Disability.
37. *CEN/TS 81–76:2011*; Safety Rules for the Construction and Installation of Lifts—Particular Applications for Passengers and Goods Passenger Lifts—Part 76: Evacuation of Disabled Persons Using Lifts.
38. *EN 81–80:2019*; Safety Rules for the Construction and Installation of Lifts—Existing Lifts—Part 80: Rules for the Improvement of Safety of Existing Passenger and Goods Passenger Lifts.
39. *EN 81–82:2013*; Safety Rules for the Construction and Installation of Lifts—Existing Lifts—Part 82: Rules for the Improvement of the Accessibility of Existing Lifts for Persons Including Persons with Disability.
40. *ASME A17.1-2022/CSA B44:22*; Safety Code for Elevators and Escalators. American Society of Mechanical Engineers: New York, NY, USA, 2019.
41. Directive 95/16/EC of the European Parliament and Council of 29 June 1995 on the Approximation of the Laws of the Member States Relating to Lifts. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01995L0016-20130101 (accessed on 16 September 2024).
42. *EN 81–28: 2022*; Safety Rules for the Construction and Installation of Lifts—Lifts for the Transport of Persons and Goods—Part 28: Remote Alarm on Passenger and Goods Passenger Lifts.
43. Tannenbaum-Baruchi, C.; Feder-Bubis, P.; Adini, B.; Aharonson-Daniel, L. Emergency Situations and Deaf People in Israel: Communication Obstacles and Recommendations, Disaster Health 2:2, 106-111; April/May/June 2014. Available online: https://pmc.ncbi.nlm.nih.gov/articles/PMC5314894/ (accessed on 16 September 2024).
44. Hosono, N.; Miyajima, F.; Inaba, T.; Nishijima, M.; Suzuki, M.; Miki, H.; Tomita, Y. The Urgent Communication System for Deaf and Language Dysfunction People. *Jpn. J. Ergon.* **2013**, *50*, 269–274.
45. Bennett, D.; LaForce, S.; Touzet, C.; Chiodo, K. American Sign Language and Emergency Alerts: The Relationship between Language, Disability, and Accessible Emergency Messaging. *Int. J. Mass Emergencies Disasters* **2018**, *36*, 71–87. [CrossRef]
46. *ISO 7240-23:2013*; Fire Detection and Alarm Systems. Part 23: Visual Alarm Devices. International Organization for Standardization: Geneva, Switzerland, 2013.
47. Flores Ramones, A.; del-Rio-Guerra, M.S. Recent Developments in Haptic Devices Designed for Hearing-Impaired People: A Literature Review. *Sensors* **2023**, *23*, 2968. [CrossRef] [PubMed]
48. Adilkhanov, A.; Rubagotti, M.; Kappassov, Z. Haptic Devices: Wearability-Based Taxonomy and Literature Review. *IEEE Access* **2022**, *10*, 91923–91947. [CrossRef]
49. Yağanoğlu, M.; Köse, C. Real-Time Detection of Important Sounds with a Wearable Vibration Based Device for Hearing-Impaired People. *Electronics* **2018**, *7*, 50. [CrossRef]
50. Hong, S.Y. Vibration-based wearable haptic feedback device and its applications. *Theor. Nat. Sci.* **2023**, *17*, 104–109. [CrossRef]
51. Yağanoğlu, M. Real time wearable speech recognition system for deaf persons. *Comput. Electr. Eng.* **2021**, *91*, 107026. [CrossRef]
52. O'Shaughnessy, D. Trends and developments in automatic speech recognition research. *Comput. Speech Lang.* **2024**, *83*, 101538. [CrossRef]
53. Jerry, L.; Yanz, J.L.; Preves, D. Telecoils: Principles, Pitfalls, Fixes, and the Future. *Semin. Hear.* **2023**, *24*, 29–42.
54. The Following Article Summarizes the Main Assistive Technologies Useful for Deaf People: "Deaf Accessibility Technology: What Devices do Deaf People Use?". Available online: www.handtalk.me/en/blog/deaf-accessibility-technology/ (accessed on 16 September 2024).
55. Seliger, H.W.; Shohamy, E. *Second Language Research Methods*; Oxford University Press: Oxford, UK, 1989.
56. Irasiak, A.; Sroka, E.; Górka, W.; Socha, M.; Piasecki, A. Deaf-friendly research. Conducting research using an electronic questionnaire. *e-Mentor* **2021**, *5*, 4–15. [CrossRef]
57. Lugarini, E. (Ed.) *Valutare le Competenze Linguistiche*; Franco Angeli: Milano, Italy, 2010.
58. Gaweł, E.; Soto-Rey, J.; Zwierzchowska, A.; Perez-Tejero, J. Trends and Future Directions in the Sports Performance of Deaf and Hard-of-Hearing Athletes: A Systematic Review. *Appl. Sci.* **2024**, *14*, 6860. [CrossRef]
59. Norasteh, A.A.; Zarei, H. Studying Balance in Deaf People: A Systematic Review Study. *Arch. Rehabil.* **2019**, *20*, 2–15. [CrossRef]