Built Environment for People with Sensory Disabilities

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People with sensory disabilities constitute a significant portion of society whose accessibility needs must be prioritized in the design of the built environment. Sensory disabilities cause a gap in the environmental information received, most commonly visual and/or auditory cues, that requires consideration to create equal opportunities and experiences for all.

Keywords: built environment ; sensory disability ; d/Deaf ; visual ; accessibility

1. People with Visual Disabilities and Accessibility of the Built Environment

The built environment has been designed by sighted people for sighted people to navigate and access, leaving people with visual impairments struggling to gather the sensory information needed to orient themselves properly within the environment [1][2][3]. Failing to consider the accessibility needs of the visually impaired, the built environment becomes hazardous and their daily activities difficult. The research pertaining to visual disabilities and the built environment was categorized into three main themes: pedestrian infrastructure, outdoor environments, and indoor environments.

1.1. Pedestrian Infrastructure

Pedestrian infrastructure refers to the built environment that surrounds walking environments, such as sidewalks, crosswalks, and curbs. For people with visual impairments, pedestrian infrastructure also includes accessibility features such as tactile paving, blister blocks, and orientation blocks. Pedestrian infrastructure and mobility are where much of the research is focused for the visually impaired, due to the complex environment that impacts the mobility, safety, and accessibility of these environments. One of the most important accessibility requirements of the pedestrian environment for the visually impaired is to facilitate their ability to orient themselves and reach a destination safely.

Atkin investigated the effect of degrees of sight loss on the navigation of urban environments and what improvements can be made for a safer and more comfortable experience [4]. The study included interviews with professionals and observed journeys for eight participants with visual impairments in and around London while sharing their wayfinding strategies on usual unaccompanied trips, using street features and landmarks, as well as their level of comfort throughout the journey. Among the participants, there were three long cane users, three residual sight users, and two guide dog users. Five of them had undergone formal mobility training. The recommendations for each group of participants were then developed based on these interviews. The study highlighted the similarities and differences between participants' needs based on the mental maps they created to predict their environment. Participants stressed the need for signal-controlled crossings, audible signals, or tactile control boxes/rotating cones, and to have smooth, obstacle-free streets to reduce the risk of collisions during their trips. On the other hand, due to variations in sight loss, assistive mobility aids, wayfinding techniques, training received, and personal preferences for streets' configurations, many discrepancies in the design requirements of the pedestrian infrastructure were underlined. For instance, while residual sight users have issues identifying the height of curbs, both long cane and guide dog users prefer the use of curbs to provide them with a more distinguishable difference between roadways and sidewalks. Also, long cane users prefer sidewalks that are not excessively wide, whereas wide sidewalks are best for guide dogs and residual sight users. These discrepancies confirm the necessity to improve the effectiveness of tactile paving guidance and provisions that account for the different grades of sight loss and assistive devices. In addition, it is important to make use of natural cues for a safer and more predictable environment with even unobstructed pathways. It is worth mentioning here that although this study focuses on understanding the differences between the different groups of the visually impaired, it was conducted on a small sample size; therefore, the accuracy of the recommendations should be further reviewed with larger groups.

A study conducted by Tennøy et al. aims to assess the quality of current Norwegian standards in the planning and design processes of tactile paving systems and their efficiency in the accessibility of the visually impaired community [5]. The review included a comprehensive review of 36 Norwegian and international standards, handbooks, and guidelines.

Additionally, it featured in-depth interviews with 20 individuals representing governmental authorities, organizations associated with people with visual impairments, and practitioners playing a role in facilitating built environments. Furthermore, two seminars were held with 21–26 attendees representing stakeholders involved in or working with facilitation for people with visual impairments, and a case study was conducted examining the previous work in a preselected bus terminal. The results of the study showed that many of the standards prioritized natural lead lines over specialized tactile paving and only suggested their use where warning is required or when natural cues are not adequately available. Based on the literature, people with visual impairments usually tend to train themselves using the naturally available elements for better wayfinding and orientation. However, the standards did not provide details on how safe and accessible built environments should be designed using natural leading elements. Instead, specialized tactile paving was described in more detail, especially in complex situations. Additionally, the results looked at whether implementing universal design can be an adequate solution and pointed out several challenges due to the variability in understanding universal design requirements among stakeholders, in addition to discrepancies between projects that interfere with one another and the delays in consideration of universal design in the planning and design stages. The findings implied a significant gap in knowledge on how people with visual impairments navigate in complex pedestrian environments, utilize physical elements in the environment, and how the design of the built environment can make it more usable for them. The study provided recommendations such as involving more practitioners and institutions engaged in mobility training for people with visual impairments in the research and providing training for practitioners involved in planning, designing, constructing, operating, and maintaining built environments.

Havik et al. performed a comparative field study and interviews investigating the wayfinding performance of 25 people with visual impairments in two shared spaces compared to two traditional spaces [6]. Shared spaces are a new design concept, also known as complete streets, where the goal is to help integrate the motorized road with an inclusive pedestrian environment. The participants ranged in the degree of their impairment, with a spectrum covering complete blindness to low vision, their age ranging between 19 and 69 years, and their assistive mobility aids, with five dog and long cane guide users, 15 long cane users, and five without any mobility aid. The participants had to complete a route, each containing one crossing, one or two turns, and walking parallel to the road. The walking of the routes was observed from the opposite side of the road, which included a schematic map of the path taken by the person with visual impairment. The test leader walked approximately 1–2 m behind the participant to intervene if the person required assistance. Assistance was given in circumstances where a participant was unaware that they had begun walking into traffic. The comparative field study results showed that navigating in an unfamiliar shared-space area is more complicated for people with visual impairments than navigating in an unfamiliar conventional area, as orientation is the main challenge in such areas. In shared spaces, the person with visual impairment, on average, took more time to complete the route, had a lower preferred walking speed, and rated the shared space design more negatively. The fully blind participants also required assistance during the route in all the shared spaces tested, as there was no curb dividing the sidewalk from the roadway. Shared spaces were consistently rated as feeling less safe, and people with visual impairments would not want to complete the trip independently. This research highlights a need for the concept of shared spaces to be addressed from the point of view of a disability to promote the idea of true space. This study was limited to four spaces in total, whereas studies with a larger sample size representing the full spectrum are needed to determine the full extent of the effects on the visually impaired population.

A survey focusing on the outdoor travel experience and the mobility-related barriers that people with visual impairments experience was conducted by Zeng [7]. A focus was also placed on the role of mobile devices and GPS technology and their impact on aiding the visually impaired with outdoor travel. Ninety-seven participants took part in the survey with varying degrees of impairment, with 64 participants being blind and 33 participants with low vision. The survey questions focused on the outdoor travel experience and the use of assistive technologies. For barriers that people with visual impairments experienced within the city, the survey emphasized their experiences when they travelled independently. Most of the participants presented the issues of public transport stops lacking auditory information (82.4%) and traffic lights without an audio output (81.4%). Other common issues presented by the participants were the failure to find the entrance of a building (64.9%), ill-formed and irregular sidewalks (58.7%), falling from unknown stairs (47.4%), getting lost (45.3%), falling because of an unknown hole (44.3%), and complex pedestrian crossings (43.4%). One of the major findings of this study is that 36% of the blind and 21% of the low-vision individuals were not able to navigate and orient themselves independently and needed sighted companions to help. This highlights the need to improve the built area for pedestrian infrastructure via accessible facilities and assistive aids. This research was solely focused on understanding the mobility-related areas without providing recommendations on remediation, but it highlighted many areas of the built pedestrian environment that cause barriers to accessibility for the visually impaired. Additionally, the study revealed that the current GPS systems lack the up-to-date map and environmental accessibility data needed for people with visual impairments. This survey identifies areas that need to be addressed, but the sample size is a small representation biased toward the infrastructure available in developing countries. This may have influenced the results, as other issues may be more prominent in these areas in developed countries.

The physical attributes that affect the walkability of the environment were investigated by Bona Frazila and Zukhurf [8]. The research was conducted by interviewing blind and people with visual impairments and performing statistical modelling on the facilities required for walkability. Two surveys were conducted to thoroughly understand the perspective of blind pedestrians and the key physical elements that impact their walkability. To evaluate the effect of each physical attribute on walkability, a linear correlation between them was assumed, in addition to the perspective of the blind individuals about the importance of the facilities that needed to be provided. Walkability was found to be affected by the effective width of the sidewalk, pavement condition, including tactile guidance, crossing facilities, and sidewalk level, physical guidance such as tactile guidance and Braille information, and security and safety facilities. These physical attributes need to be carefully considered during the planning phase of the pedestrian facilities to serve walkers with visual disabilities.

1.2. Outdoor Environments

Outdoor environments such as city parks present unique challenges to the visually impaired, as there is less information available to them. These types of environments often bring out feelings of discomfort and a need to rely on a sighted guide to use these spaces. The overall area has not been researched as heavily as other areas of visual disabilities.

Siu performed a case study on the urban parks in Hong Kong with 12 people with visual impairments to determine the overall accessibility of the park and the key directions that lead to complete social inclusion for everyone [9]. The participants were interviewed to understand the overall accessibility of urban parks, and a combination of site studies and field observations were used during these interviews. Government officials and planners were also interviewed to understand the current standards. Six parks of various sizes in three different districts of Hong Kong were visited. The inaccessibility of urban parks for the visually impaired was found to be related to three main areas: identifying and approaching parks, the overall environmental setting, and the facilities inside the parks. The participants had accessibility issues identifying and approaching parks, as they experienced mental stress from trying to locate the park and often had to memorize the route to the park. They often had difficulty entering the park independently or without the help of a sighted guide. The overall environmental settings of the park were found to be inaccessible due to the lack of tactile information about direction and orientation, and little to no auditory information was available. Information about the facilities within the park and their accessibility was often not provided. Therefore, the study suggested providing further assistance by categorizing the information into in-advance and on-site. Although the research highlighted the problem of the limited and poor-quality support provided for people with visual impairments to navigate urban parks independently, it only considered a small sample size of 12 participants.

The barriers that limit the experience of people with visual impairments exploring the outdoor environment, in addition to the role of technology in improving these experiences, were investigated by Bandukda et al. [10]. After interviewing seven people with complete blindness and using thematic analysis, common threads and themes were identified. The participants varied in their location and age (20–60 years). The interviews, which were conducted over the phone and video calls, contained generic and specific questions about the participants' experiences. Three key themes were analyzed: independence, knowledge of the environment, and sensory experiences. The "independence" of a person with visual impairment is often negatively impacted by the lack of wayfinding information and landmarks, which makes the outdoor environment more physically and mentally demanding. The "knowledge of the environment" theme reflected the fact that a person with visual impairment will almost always need to be accompanied by a sighted companion. The need for the sighted guide stems not only from a need for help with orientation but also for a description of the visual environment. Finally, the "sensory experiences" theme helped people with visual impairments identify the environment around them. These sensory characteristics can be a change in tactile sensation from the ground, sounds of flowing water, and sounds from birds, which help indicate the presence of trees. The study revealed the gap between existing technology and human–computer interaction (HCI) research in outdoor environments, the need to provide an independent navigating experience for people with visual impairments in outdoor environments without the need for sighted companions, and the lack of natural landmarks and clues that force the people with visual impairments to use navigation apps that lack accessibility features.

1.3. Indoor Environments

Navigating indoor environments represents the biggest challenge for people with visual impairments, especially when exploring unfamiliar spaces without clear guidance and the availability of assistive aids [11][12]. Jeamwatthanachai et al. performed a survey to understand the challenges, behaviors, and strategies used by the visually impaired when navigating an unfamiliar indoor environment [13]. The survey included 45 participants of whom 15 experts and 30 people with visual impairments commented on the accessibility of the indoor environments. Of the 30 people with visual impairments, 22 self-reported as blind/severely sight impaired, and eight participants were sighted impaired/partially sighted. Both the sighted and visually impaired completed 18 questions, which were split into five categories regarding indoor navigation by the visually impaired. Five types of buildings were examined, which were further broken down into four room types and analyzed based on the level of difficulty and confidence in using the space. Every person with a visual impairment was asked to rate the level of difficulty (easy, moderate, or hard) and their level of confidence in navigating space (no confidence or confidence). After rating the buildings and spaces, they were asked to give comments on their reasons for the level of difficulty or lack of confidence in navigating the space. The results of the study confirmed that the main challenge facing people with visual impairments is the fear of navigating unfamiliar indoor spaces independently and the time it takes them to become familiar with the space. Therefore, they need to have a sighted guide before building the confidence to explore these spaces with the help of assistive aids. The recommendations are to have different alternatives for navigation that help them to develop confidence and create a safer environment, in addition to providing information about the obstacles and barriers that might impede their accessibility with the help of landmarks and environmental cues such as light, noise, and smell. The study showed that certain types of buildings and sizes of rooms do cause a large difficulty in the accessibility of the indoor environment. While the deduced conclusions and recommendations are useful, they were based on a very small sample size that may not be representative of all people with visual impairments.

2. People with Hearing Disabilities and Accessibility of the Built Environment

The everyday built environment is not typically designed for auditory cues, even though they play a large role in the ability to communicate within space. As communication is often done verbally, those in the d/Deaf community may be unable to communicate if visual cues are unavailable. The research revealed that much of the research related to sensory disabilities focuses on visual impairments, and fewer studies investigate the requirements of people with hearing impairments. Furthermore, indoor environments appear to cause more barriers for people in the d/Deaf community. Without actively creating a barrier-free space, the ability of people with hearing impairments to communicate with others when indoors will remain limited. The issues presented in indoor environments for people who are d/Deaf are largely related to communication and safety. Since most of the barriers to accessibility that the d/Deaf community experiences are related to social problems, most of the research related to the built environment is looking at how to improve barriers to social problems, such as improving communication.

As an attempt to cope with and improve the surrounding indoor environments for the d/Deaf community, DeafSpace was introduced in 2005 as a set of architectural design space principles that account for a correlation between the built environment and the senses [14][15]. The principles of DeafSpace were collaboratively developed by the hearing architect Hansel Bauman and students at Gallaudet University, an American university designed for the accommodation of students who are d/Deaf. The five concepts of the DeafSpace are “Sensory Reach” by utilizing visual cues to promote awareness of the surroundings, “Space and Proximity” by maintaining appropriate distance during conversations to accommodate the signing space, “Mobility and Proximity” through keeping an adequate signing space between individuals walking while talking, “Light and Color” through modulating natural light attuned to d/Deaf eyes, and finally “Acoustics” through minimizing sources of background noise. Edwards and Harold [14] discussed the principle of DeafSpace relative to the concept of Universal Design. While Universal Design focuses on providing standardized and universal barrier-free spaces for all types of people, it was criticized for failing to consider the particularities of the d/Deaf community. The study highlighted some of the criticisms of DeafSpace. Due to the limited number of buildings adopting the DeafSpace design, it may not meet the end goals of the users. An example is the implementation of curved corners, which are designed to allow the d/Deaf to see farther around them and avoid having people bump into each other, but in practice, people tend to hug the corner. Overall, DeafSpace emphasizes flexible and innovative designs that account for acoustic environments and that should not conflict with Universal Design, yet understanding their relationship together will require time. There are still uncertainties about the spaces DeafSpace can produce specifically for the d/Deaf community; otherwise, it will just remain a set of rules and principles.

The reliance on visual emphasis has been criticized in Western architecture as it alienates people with different needs. For that reason, Pérez Liebergesell et al. investigated the potential to connect people by exploring the experiences of George Balsley, an architect who is d/Deaf who utilized vision in his designs reflecting the interaction of visual and spatial dynamics in sign language [16]. The study was based on interviews and observations about the design of his building, the Sorenson Language and Communication Center (SLCC) in Washington, DC. The SLCC resides at Gallaudet University; therefore, its accessible design for the d/Deaf community is highly important. It is important to note that only the architect was included in the interview to understand his design. The goal of this study was to understand the designs that Balsley implemented to increase the accessibility of the building for the d/Deaf community. Balsley noted that one of the main concepts to consider when designing a space for the d/Deaf is the need for visual communication and the space required to implement it. To have the required space for visual communication, it is necessary to design elements such as open spaces, glass walls, rounded corners, and automatic closing doors. The d/Deaf community is reliant on visual cues to experience their environment, which leads to the design being focused on translating sounds into visual cues. The SLCC building shows this with the decision to move the elevator into the center of the atrium and make it clear so that individuals who are d/Deaf can see if the elevator is moving or not.

To further investigate the visual needs the d/Deaf community relies on when using sign language, Azalia et al. discussed the concept of spatial proximity and what space configurations can support their communication in public places like cafés [17]. Proxemic space considers not only the amount of space needed for sign language but also the preferred distance that the conversations take place at for the comfort of the individual. Anthropologist Edward Hall introduced the concept of interpersonal distances characterizing Western culture, where the proxemic zones are broken up into four categories: intimate, personal, social, and public space [18]. These proxemic zones stem from the tactile and visual reach needed to communicate. When designing layouts within buildings to accommodate the d/Deaf community, the target zones for design are the personal, social, and public spaces. Personal space is considered 46–120 cm of sensory reach, and it is the optimal space for sign language and lip reading with friends and family. Social Space is considered 120–370 cm, which is optimal space for sign language between acquaintances. Public space is considered any space above 370 cm. The results were used to analyze Kopi Tuli, a café for the d/Deaf community, and the observations showed that providing a variety of proxemic zones, with the arrangement of tables and furniture and the use of semi-reflective surfaces and transparent materials, allowed for a variety of the d/Deaf community to feel comfortable while still having easy communication. This is shown by the variety of social and public proxemic zones being available, allowing the d/Deaf community to pick the areas that feel comfortable and accessible to them. It is important to note that the experiment took place in a café considered a place for the d/Deaf community.

Another study was conducted by O'Brien, where five academics who are d/Deaf were interviewed to understand and experience how the academics who are d/Deaf navigate the physical environments of their workplaces at Higher Education Institutes (HEI) [19]. With the concept of DeafSpace expanding into how individuals who are d/Deaf change their environment, many individuals in HEI must adapt their workspace to fit their needs. The walking interviews provided the ability to see how sign language communication is affected by the built environment, or the DeafSpace concept of perceived space. Several of the hallways and pathways did not provide enough width for two signing individuals to walk side by side, as there was not enough space to comfortably articulate and see the whole signing space. Another barrier to the accessibility of pathways and hallways was the obstacles, which needed O'Brien or the participant to guide each other around during the conversation. Adaptation within the perceived space is also important for the safety and accessibility of people who are d/Deaf. Examples of these adaptations include fire alarms with flashing lights, flashing doorbells, or fire alarms that connect to the individual's phone. The DeafSpace principles often cause a conflict between d/Deaf and hearing values, such as the concept of tactile sensation from floorboards. While the tactile sensation helps the d/Deaf identify people around them, they also have a concern about the amount of noise the floor makes, as they do not want to disturb the hearing people around them. Other aspects of making the spaces 'deaf' are through the concept of the lived space, a sub-concept of DeafSpace. This is shown through adjustments that the people who are d/Deaf make the space more accessible to them. Within the context of O'Brien's conversation with individuals who are d/Deaf in HEI, moving desks to make the office more deaf-friendly was a common one. This consisted of moving the desk to face the door or strategically placing mirrors, so they were aware if someone wanted to enter the office. Another concept discussed was the conceived space, which identified issues with university planning. The main issue addressed was the lack of windows on doors, as without them, individuals who are d/Deaf cannot tell when someone is trying to enter their office. Overall, the study strongly emphasizes that even minor adjustments that account for individual spatial experiences can foster an inclusive environment for all while also maximizing the productivity of academics who are d/Deaf in their workplace.

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