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Review of Various Assistive Technologies in Healthcare

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Abstract

About 8% of the population in India is multiply-disabled, of which significant sections constitute women due to lower literacy rates, social factors, and lower grade health facilities. Disability affect the normal day-to-day functioning of an individual and the assistive technologies are useful tools to provide a workable solution to mitigate some of the disability related issues. This paper reviews models and prototypes of various assistive technology available worldwide. These technologies may cater to a single impairment's needs but can also be used by a multiply disabled person after some modifications. Such models fail to impact developing nations' markets. The work done to mitigate the effects of vision impairment hearing and speech impairment is explored. Finally, the technological and research challenges are discussed in developing assistive technologies and devices for different disabilities.

1. Introduction

Disabilities can occur when a person lacks the capacity to use one or more of their senses or their motor skills in an efficient manner. Although medical research into cancer, diabetes, and other diseases has improved, little has been done to enhance the living conditions and circumstances of those who are disabled. For those with various disabilities, there is also a shortage of support and research opportunities available. More than 26 million Indians have some sort of impairment, according to the 2011 census. Of these, a total of 7.9% suffer from multiple-disability [1], as shown in Figure 1.

According to the World Health Organization (WHO), about 1 billion individuals (or around 15% of the global population) are disabled in some way [2]. This number is expected to rise as the world's population ages, the number of individuals who become disabled increases, and the number of people suffering from chronic illnesses rises. More than half of persons with disabilities around the world are living in poverty and have inferior health outcomes and educational chances than those without impairments [2]. Disability rates are higher among those with less education than those with more education. A major factor in their marginalization is their gender and disability exclusion from society [3].

Disability can be of two forms: *congenital disability* (disability by birth) or *acquired disability* (disability due to mishap). Persons with disability have varied responses to their condition based on gender, age, socioeconomic factors, sexuality, ethnicity, or cultural status. Assistive technology has enabled a myriad of technologists and researchers from varied branches to develop devices to equip disabled people. The main idea of assistive technology is not to mitigate the disability or the incapacity of a person but simply to give a solution to facilitate their daily living and achieve normalcy in their lives.

It becomes paramount to assess the available technology, especially in developing nations, because of a bidirectional relationship between disability and poverty. Children with disability are unlikely to have access to education than normal children; this weakens their employment opportunities and productivity in adulthood. Poverty leads to an increased threat of disability because of poor living and unsafe work conditions, lack of clean water, low birth weight, and unavailability of suitable medical attention. This paper reviews the existing technology and devices used to assist disabled people. These devices are mainly used as a means of communication or to help the daily living. The various factors like their design, advantages, and shortcomings are explored.

2. Access Technology

With people becoming more conscious and realizing the need to uplift the quality of everyday living for the disabled, many devices have assisted them. Many of the following discussed devices have been modeled to help a particular impairment, which is sometimes incapable of catering to the need of persons with multiple sensory impairments. Following is the categorization of various access technologies available. Blind technology: enables a person with loss of sight to interact with or access the environment directly or indirectly.

1. Deaf technology: enables a deaf or hard-of-hearing person to communicate via sign language or visual cues.
2. Blind-Deaf Technology: facilitate a blind and deaf person with effective communication and position information.
3. Technology for mute or deaf-mute: assist a person who has a speech disability or is both speech and hearing impaired by fingerspelling, text, or visual cues.

We explore the work done in the above cases. As one might notice, even if one sensory organ is not functioning correctly, there arises the demand to develop or utilize technology that helps carry out day-to-day work, which heightens the use of other functioning sensory organs. Sometimes this leads to a very common situation where another human being is seen helping a person with a disability. Few past experiences have shown that many assistive devices are not as helpful as proposed or enhance problems rather than lower them [4]. At the industrial level, the main reason for the failure of assistive devices is the high investment at the initial level and the market being very limited.

3. Technology for the Blind

Loss of sight is usually associated with independence loss due to low perception of the environment. Many students and researchers under the Assistive Technology domain have taken up projects to aid the visually challenged to overcome this setback. Many degrees of vision loss range from color blindness to far-sightedness, near-sightedness, etc. Blindness is a situation where the loss of vision of a subject is to a degree where vision substitution devices and technology have to be used for visual aid. Blind technology helps substitute the sense of imagination with aiding another sensory organ to "see." There are many tasks a person with loss of sight would need help with, such as navigating either outdoors or indoors, reading and writing. It is difficult to solely depend on guiding cane, specifically in railway stations or stairways in today's dynamic world. Seeing-eye dogs are declining, and personal assistant robots are expensive, limiting their use worldwide [5].

a) Orientation Devices

The most challenging task for a blind person is to navigate within his surroundings. Navigation is defined as the movement control and planning process required for an operating body to move from one place to another [6]. A blind person usually moves towards the intended destination through closest contours; this method is inefficient and leaves no alternative when met with a series of obstacles [7]. It becomes impossible to walk on the road in modern cities, as there are many alternate routes to reach a destination, enough to baffle a sane person. The classical solution to this problem has always been a human guide who guides a blind person through an environment. This may be a philanthropic solution, but it is quite unproductive for human resources.

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To give a plausible solution to this problem, many researchers [8] have integrated GPS with mobile technology or portable devices to assist blind people with a sense of direction. They have given effective information about the location and routes to his destination. GPS has been widely used because of its cost-effectiveness and ease of implementation. Global Positioning System (GPS) is the most widely accepted absolute location providing technology. It uses satellites spread over the globe to track the devices that support GPS to provide absolute locations [9]. The limitation with GPS is that it does not give details about all of the most effective routes for the blind and includes inadequacy in the accuracy of data since the GPS is insensitive to data of the real dynamic environment. This inaccuracy can prove fatal for the blind. GPS is unreliable in the case of indoor navigation. It also needs to be connected to the Internet, which is a drawback for developing nations like India, where signal fading and loss of signal strength are common issues in rural areas.

RFID (radio-frequency identification) technology has also been used as a destination-tracking device indoors and outdoors. It gives an absolute location concerning the previous base centers, which have already been set up [10]. Further, a Wi-Fi-based device for absolute positioning has been developed in research labs. The fixed base station accumulates the signal strength of a mobile station, which is sent to the central unit for processing. This central unit calculates the relative distance from this point to the target place and gives the best route possible [11].

Orientation devices using infrared sensors were implemented using tactile maps and a beacon system that enabled the user to navigate through the street or a building. This method is also effectively guided through a shopping mall [12]. Many devices have incorporated the guiding cane mechanism using a coupled camera and distance sensor (Passive range Pattern Sensor) to form an obstacle avoidance system by sending the position data of the obstacle concerning the user. The data is unreliable when the environment is in motion [13, 14].

Quite a few research papers are also based on obstacle detection, which can be utilized to aid vision impairment. In reference [15], multiple sensor-based systems are described which can be used for the obstacle detection system. The critical specifications for sensor performance include a range of detection, sensitivity, and reflection materials. The design of this device has been made with a focus on its wearability rather than portability.

A wireless assistive device was fabricated and tested using a Tongue, Electro-tactile System based on the sensory substitution concept. The data acquisition part of this system includes a pair of sunglasses mounted with a camera, which transmits the data to a host system. This computer-primarily translates the camera data into a pattern of command, transmitted to the user with the help of an array of electrodes with 33 pins. The circuit placed to control this array generates a low current of 1.62 mA. The transmission of a signal from the host computer to the Electro-tactile device takes place with the help of Bluetooth. This proposed tactile device has been tested, and the problem they faced was that response towards the voltage range varied from person to person. Also, the communication and response time should be improved [16].

Another prominent Navigation Prototype was described in [17], called the Blavigator Prototype. It employs an Interface Module, which comprises a text-to-speech to provide the menu navigation, a 4-button command pad to enable the user to use the GUI of the module, and vibratory devices are fixed around the user's body to give directional cues. This version also can save the Geographical information relating to Indoors and Outdoors and manipulate the path proposal to the Point Of Interest.

An evident hiccup for a visually challenged person is observed when they have to purchase products in the supermarket without the help of others. In [18], a low-cost smart shopping facilitator has been described, which uses RFID (Radio Frequency Identification) system to identify the products using RFID tags placed on the shelves. This is interfaced with the PIC Microcontroller, where the unique EPIC (Electronic Product Identification Code) is sent. When the user selects his product while listening to the audio clip describing each shelf and product, the selection is made using push-button

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mounted on the module. The list is sent to the billing counter using Zigbee Technology. This prototype is easy to build and implement also would be a real shopping facilitator to the visually impaired.

Another method to shop independently has been described in [19], where a portable camera is used to capture images. This project is used for reading the labels printed on the products. To isolate the background from the product of interest, the user must shake the product, so an ROI (region of interest) is set. Using text-localization techniques, a dataset is also created which can be used with the same product any other time.

With the loss of vision, a usual setback is seen with the lack of ability to perceive emotions and recognize people around. To rejoinder this problem, a smartphone-based system called interactive mobile affect perception system (iMAPS) was proposed in [20], which uses the facial feature, and head pose detection of the person of interest and matching happens across the database. Also, affective states were mapped using facial expressions. This system aims to help the visually impaired in social interactions. This system currently identifies a few emotions effectively. It is in the process of perceiving other emotions effectively. Also, a separate Graphical Processing Unit has to be employed to maximize the processing power and limit the response time.

The above solutions are unreliable as they warn of hazards and objects in the user's path and not in a wider-scene sense (*field of view)*. None of the devices described above detect water puddles and potholes, which can be hazardous for a disabled person walking on the road. The other type, which is complex and expensive, maps the front environment usually gives audio cues, which puts a lot of stress on the audio of a blind user. Many devices are cumbersome to carry, making the user's incapacity prominent to the rest of the world. Wired mobility devices make it uncomfortable for them to tether, and also, any loose connection could prove to be a hazard. Until these devices are tested profusely, they can't be rolled out in the market.

b) Reading Devices for Blind

Apart from these obstacle-avoiding techniques for visually impaired people, there has been considerable research in text-speech or screen reading techniques. As education is necessary for every individual to lead an independent life, it is important to make it possible for every visually impaired person to have access to this world of knowledge. The standard requirements for reading include that different methodology should be employed to read in various types of activities. The reading system should provide a bookmarking system and navigation between the table of content and index and content. Also, a good description of graphics and images is a high priority.

One of the most notable works that most of us are familiar with is the invention of Braille by Louis Braille in the year 1824 when he was of the age 15 and had lost his eyesight owing to a childhood accident. Braille characters are small rectangular blocks called *cells* that contain tiny palpable bumps called *raised dots*. The different arrangements of these dots distinguish one character from another. Braille is not different from sign language but a tactile representation of the written one.

Braille literacy improves employment opportunities for the blind and also increases their productivity. It also allows users to read at their own pace quickly backtrack and re-read when something is not fully understood. There is only 5% of the printed material available in Braille. Of this printed material, bank statements and personal information is not available in Braille, so someone has to read it out, which puts privacy at risk. There has been a decline in Braille users due to advancements in technology and ideology in educating the visually impaired. Still, Braille is considered at the paramount of imparting education to unsighted children in many developing nations.

To improve the literacy rate among blind candidates, methods employed to make reading material accessible to blind readers are *speech synthesis* and *optical character recognition*. It is the process of converting text to a digital form. One of the first screen reading machines developed was by Kurzweil Computer Products [21]. This machine was about the size of a refrigerator and had been embedded with a processor, scanner, and a speech-

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synthesis box. This was a step towards putting the aural faculty of the blind to use.

In this day and age, the web has become our next best friend. From shopping guides to online classrooms, social networking, movie promotions, and staying connected has become important for everyone. One of the significant works has been done towards making websites accessible to blind users. Section 508 of the Rehabilitation Act under the US federal government clearly states that web developers should use more text on a page rather than graphics so that it can easily be converted to speech or Braille. In this method, the expense will not increase. However, the basic rules are overlooked to make the website more interactive and "good-looking." The W3C (World Wide Web Consortium) has faced a setback in making websites accessible to every member of society, so it framed WAI (Web Accessibility Initiative) [24]. The WAI elucidates the principles and rules to design a website accessible to the maximum range of users. It is compatible with a diverse range of assistive technologies in the present and the future.

By keeping the guidelines of WAI in mind, a web accessibility tool has been described in [25]. This tool analyzes the source code of the website statically to find occurrences of any code snippet which violates the WAI rules. This tool then singles out the problems inaccessibility of the website and suggests possible remedies and alternatives for that particular code. This tool can also fix a problem on its own, which is subject to change with the tool's effectiveness in identifying problems in source code.

One of the major deprivations caused by visual impairment is the problem of accessing data or information through visualization techniques like tables, graphs, charts, and networks.

Various browsers enable screen readers; although they are cheap, they have some defects like graphical content cannot be converted to speech, and multimedia content also becomes difficult to convert. Also, the translation of a webpage is very slow relative to the cognitive speed of the user. In [26], an Auralization approach is described where the reaching time of the speech to the user is minimized. The computational time has been considerably reduced to convert text to speech, and images headings and descriptions are also converted to speech. Also, if the user requires a particular topic, the layout makes navigation on the web page more accessible.

Inaccessible technologies hinder a special person's need to find and efficiently use information. A wearable camera system, which can automatically find and track text regions in surrounding scenes [27]. Such systems need to be integrated with various output systems like speech or Braille or tactile cues, which would enhance its usability. These can be used in public places, which would boost their confidence to travel independently.

An Electro cutaneous Stimulation System for Braille Reading [28] was developed using current and voltage stimulations to obtain tactile cues on the fingertips of the user. Since Braille is universally accepted and simple to understand, current and voltages in two prototypes modulated Braille cells, where current stimulation presented better results than voltage stimulations. Since different users have different fingertip impedance, there was variation in the current threshold value used. This system needs much improvement to analyze more optimum parameters of the stimulus, ensuring much better recognition of the characters in Braille reading.

Working on pattern recognition, a Voice Control application was developed for a reading assistive device for the visually impaired, as discussed in [29]. The application is used in conjunction with image processing and non-contact IMAQ. This can also convert the printed material to speech and further improve the visually impaired persons' reading ability. This is an adequate method to improve the literacy rate amongst them. Also, good methods for image processing should be used to make this module a better technology to identify strings of the letter in written or printed material.

Identifying text characters is comparatively easier than identifying mathematical characters like fractions, superscript, subscript, matrices, logarithms, integral, differentiation, trigonometry, etc. Usually, the text is presented to the visually challenged either in the tactile or audio form. Presenting mathematics to blind students at a higher

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level becomes more and more challenging as the notation gets tougher and complex, which cannot be represented using the tactile form at least. Mathspeak [30], an audio method of presenting the mathematical formulae to visually challenged, has been described. Fraction is represented as x over y, Logarithms as log base n of k, etc. This is the only known high-level mathematical representation for blind students available to the authors. It is ingenious and unique, as it will allow blind candidates to learn and grow in the field of mathematics.

The fundamental stumbling block in the lives of blind people is that they are unable to comprehend or perceive the readings on household devices. These household devices have a keypad with an adjoining LED or LCD screen, which gives an insight into the temperature or the device's condition. These readings also prove to be instrumental in controlling the devices. Clearspeech, a digital screen reader, was described in [31], where the image of the reading is taken using a handheld camera, and the surrounding noise of the image is filtered using image processing. These readings are then matched with an existing template using character recognition and converted to audio signals. The web camera used has low quality, and it lacks auto-focus. Also, some devices were inaccessible, like scrolling screens, and the audio output has to be improved to reach out to deaf-blinds.

4. Technology for the Deaf

With the technological advances, there has been an increase in hearing enhancement technology for those who are hard of hearing. A person with hearing loss needs communication independence at home and, if applicable office environment. Also, the demand increases to clearly distinguish the sound of interest from noise in a quiet and loud environment.

Fascinatingly communication was available to deaf people in a telegraph system even before it was available to anyone else. Also, the movies were silent, and text was conveyed in written form to the audience. The two basic forms in which deaf people communicate are *sign language* and *text.* Analyzing these two forms, we realize that neither spoken languages nor sign language are universal. All places have their local dialect, which has different grammar rules. Even sign languages have punctuation, spaces, and words to communicate visually effectively. It becomes challenging to understand or comprehend if a deaf or hard of hearing person relocates from his native place. Textual conversion of everything is a prolonged process, especially for people who know how to sign; hence a textual form of communication is not an adequate substitute.

Sign Language has been a natural way of communication for the speech and hearing impaired. Sign language may be seen as a combination of hand and arm movement with varied facial expressions, giving insight into their emotional state of mind. Head movements are sometimes added, and every few signs are personalized to convey a complete sentence or unique words. Sign Language varies from region to region, from language to language, and from culture to culture. Also, in a few cultures, the sign language is different for both men and women. Occasionally instead of using a hand to sign and communicate, two hands are simultaneously or periodically used to communicate [32]. These points and prior research work should be carried out while making any sign language translator to text or speech or vice versa to achieve maximum productivity and reach a maximum number of people. While designing web-based or mobile applications, designers and developers should always keep in mind the target group of their application.

Analysis from various research papers and previous works has shown that not much progress has been made to enhance the lifestyle of deaf people (severe hearing impairments). Most of the work has been done in two categories, based on usage at home or outside. Out of all the commercially available assistive devices, the former is more likely to be found. While modeling hearing assistive devices, it becomes essential to understand the nature of the user's disability as hearing disability has a lot of different classes based on their response to the sound. In this paper, various technologies that have predominately considered a severe hearing disability but can also be used by hard-of-hearing users are reviewed.

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As early as 1982, electronic mail was reviewed to be one of the best communication methodologies for deaf people. In the 1980s, many disabled members were discontinued from services because they could not perform as well as the "normal" employees. In [33], E-mail is described as an efficient way to communicate between two parties where one or both may be deaf. E-mail is fast and doesn't give out the disability factor of the user. It also enables the users to pass on information to the masses conduct discussions via E-mail so personal meetings are bypassed. The major drawback of E-mail described in this paper was its incapacity of sending emergency messages to friends and family, which has been improved in this 21st century by many of the mail service providers.

It becomes challenging for a deaf or hard of hearing person recognize the speech of multiple speakers simultaneously. In [34], a solution is reported using a ViaScribe Speech recognition application developed by Learning Consortium and IBM. This application provides real-time captioning of multiple speakers simultaneously and issues visual cues for pauses. ViaScribe records and synchronizes the speech of many speakers. Each speaker is identified with a unique ID, which is also used to categorize the speech of various users. Also, another way to eliminate this problem has been proposed in [35], where an LED is used to identify the speaker in a discussion, and this may aid a deaf person to lip-read rather than being confused in such situations.

There have been numerous hearing aids in the market from various companies. The key feature that sets these aids apart is the frequency response. Frequency response is directly related to the hearing loss of a deaf person. Before a hearing aid is rolled out in the consumer market, several tests are conducted to determine the best performance kit. Also, if the device is not selected correctly, there is a chance of an artificial increase in gain in frequency response, which may cause health damage.

Since the inception of Smartphones, video calling and videophone applications have attracted deaf users towards it. Even though they were already using phones to send and receive text messages and e-mails, sign language seemed normal. It conveys more than the message than the emotion and sentiment behind the conversation or opinions [36].

Gesture Recognition technology has been booming since the introduction of embedded systems in the industry, with its integration with the software and hardware requirement fulfilled. People who cannot hear usually can speak but are sometimes very conscious of doing so because of fear of the "deaf voice" or are too loud. For this reason, many researchers developed technology for deaf individuals who would be able to sign to convey their thoughts and opinions, which was usually very costly or not portable, making it difficult for the product or device to penetrate the market. HandTalk from the CMU has tried to mitigate the above-listed problems by using five flex sensors which give a different reading as they are bent to different degrees, so a combination of such degrees would provide the particular letter or alphabet. This data was sent over Bluetooth to a mobile phone, which was converted from analog to digital, and then using a text to speech converter was used to "speak out", the conversation of a deaf person [37].

One of the earliest versions of a virtual signer was "*Simon the signer,*" which recorded a person's facial expressions and hand movements. This was then converted to text to be read by the deaf person. This methodology was also used to provide real-time captioning of a video sequence or TV program. The initial results were lagging behind the motion video. Also, the conversion to text was easier only when short sentences were used. Another hurdle this methodology faced was that recording one particular movement required a lot of sensors, from facial sensors to hand sensors to note down the face and hand motion.

There has been a swell in the 3D avatars for the deaf. Hence the Web3D consortium has set rules to design 3D signing avatars. This also makes many developer tools available, and deaf people themselves can use these to make personalized avatars user-friendly. At the University of Tunis, a WebSign net was developed where gestures are classified into signed language. They use an M-H (Movement-Hold) model where hand shape, orientation, and location are classified using an already saved database, making it more precise. Also, using the joint-to-joint distance calculations

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minimizes the errors. Further advancement in this area would be using much better neural networks and eliminating any language convertor errors concerning grammar.

An advanced speech communication system for deaf people was developed to help deaf people easily communicate with the outside world. One of the modules of this project includes Spanish to Spanish Sign Language Converter, where a 3D avatar is taken as an aid. Also, another module, which was developed, was the Spoken Spanish Generator from a signed language using a language translator and text to speech converter [38]. The difficulties that users faced in using these modules were the artificialness of the avatar. Also, there were many mistakes in the representations of signs, grammar, etc., which sometimes led to misinterpretation of the original message.

A mobile-based sign language interpreter was developed by researchers in India [39]. This tool would enable people who do not know sign language to communicate with deaf people. The speech or voice is taken as an input and stored in a cloud database, which is further converted into text, and this text is converted into sign language using 3D based web application. The advantage of this system includes the accessibility improvement, and since the usage of phones has been increasing, this method opens the door of mobile communication for the deaf community also. The problem, which should be eliminated in this project, should be that the database should be increased to include personalized signs. Also, grammatical errors were faced during its evaluation, which resulted in misinterpretation of the meaning of the conversation. Furthermore, it is cloud-based mobile computing which limits its use in places where there are continuous 3G networks or Wi-Fi.

Another similar approach enables deaf people to communicate effectively with non-hearing disabled people by using smartphones. Smartphones nowadays are equipped with high-end sensors like accelerometers, gyro sensors, microphones, etc. In [40], the authors use these sensors to communicate in environments like restaurants, gas, or bus station. By shaking the mobile phone from left to right, negation can be expressed or moving the phone in an up-down motion, which can be used to say yes. The authors use the circling of mobile phones to ask interrogative questions like when what, and where. Also, the developers had a database with related questions to a particular place like a restaurant, subway, etc., to save the input time.

Sign languages have been diversely about the area or the person who is speaking, but still, not every language has been converted to sign language and is widely recognized. This poses a loss of culture, language, and heritage for a deaf person. To decrease the effect of local language depreciation in sign language, the authors of [41] have described an improvisation to the database of the Signwriting system. It is a system where sign language is identified for a particular English alphabet, and signs are written into the device to save them for documentation or memories. This database would be available to everyone using the system, which would increase the outreach of a particular sign language.

Recently many individuals with hearing impairment have been seen driving, or their inclusion in society and public places has increased by good numbers. The difficulty faced by many of them is the need to interpret the external environmental sound and noise to determine their action. For example, if a deaf person is driving, it is unlikely he will hear the sound of an ambulance or any other emergency noise. Even if devices are available to enhance the sound, noise filtering is done very inefficiently, and the sound of interest is suppressed most of the time.

A concept of an assistive hearing device as described in [42], where advanced neural networks and learning algorithms make it possible for the device to enhance the surrounding sound. The idea revolves around pattern recognition, which filters sound from broad spectrums to indicate urgency. To incorporate all sorts of sounds like that of a car or that of human beings or animals, the classifier for the learning algorithm must be flexible and carefully updated from time to time. This whole module can be consolidated with the help of a smartphone, which also provides many signs for speech translators. Also, the user interface to alert the user was designed as a vibrotactile interface or a haptic belt. The areas of concern are the application's power consumption nowadays; there are many power glitches in smartphones. Also, the

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processing time has to be fast for the user to interpret and react. However, this idea is very novel and would be very revolutionary in the social inclusion of disabled people.

A person suffering from hearing loss is at a disadvantage as alerting systems like an alarm clock, oven timer, etc. Such systems are futile. But there have been many devices in this field, including wired (it has an external bed vibrator) and portable vibrating clocks, which are also used to wake up heavy sleepers. Usually, smoke and fire alarms are wall-mounted, and the sirens are not heard by the aural impaired, which can be seen as a hazard at many places. This can be implemented as a neon light and can be coupled with a portable device like mobile phones of deaf people to be informed of the emergency. Answering the doorbell when it is rung can be an invisible challenge for those with hearing loss. This is responded to by the modern doorbells by either flashing light whenever someone is at the door or by placing multiple receivers in the house, which can be synchronized with portable devices like vibrators or mobile phones [43].

5. Technology for the Deaf-Blind

Till now, devices and technologies related to assisting blind people or the deaf community were considered, but there are those also who suffer from multiple disabilities like being deaf and blind simultaneously. As described in previous sections, vision loss may benefit from audio-assisted technologies. Those who are deprived of the sense of aural faculty may use textual or sign cues to carry on their daily lives without being hindered a lot.

The condition of Deaf-Blind may occur by the Usher’s syndrome also where there is a loss of hearing at birth and people under this group experience gradual loss of vision as they age. Some of these people are familiar with sign language, and from an early age, they have started their education with Braille text. For people who are deaf-blind, the only way to communicate or perceive their environment is by tactile technology used in diversified ways to accommodate various activities to be carried out by them. In a developing country like India, about 500,000 people are suffering from a combination of deafness and blindness, which makes them a marginalized group. Since the literacy rate isn’t very high in the disabled group, disabled people in developing nations are devoid of communication and information, which forms the basis for any country to progress [1].

Human beings are social creatures who learn and develop skills using their experience and the experiences of others around them. The deaf has other senses like seeing and touch, giving a vivid insight into the environment. Many devices have been proposed to enhance the quality of their living. Also, although blind people cannot see, their other senses like aural and smell get heightened and can be used by devices described above to give them the sense to see. But deaf-blind people are left only with the sense of touch. Some people who are not familiar with Braille face a problem where they are always dependent on an interpreter to communicate. They can independently talk to people who are familiar with sign language. In this 21st century, when everything is becoming autonomous and independent, it is time to review some technologies used to escalate the experiences in the lives of deaf-blind people.

While crossing the road, the critical information for the deaf-blind would be traffic density, horn sound, people shouting, and the steep drop-offs like potholes and construction sites. Information like the size of nearby leaves or the sound of dishwashing is not essential. While for communication, the needs include visual cues like facial expressions or laughter. The textual or pictorial information, vocal information like accent, the intensity of speech, and speed are all critical. While devising devices for the use of deaf-blind and using technologies to achieve uninterrupted tasks for daily living, the needs and requirements of the people should be kept in mind before prototyping.

A communication method described in [44] uses a smart glove, which is used to bridge the gap between the English text and Braille text. The glove is to be worn on the left hand, with the control unit worn on the wrist. The user inputs the text to be transmitted over grade-1 Braille using their right hand, and it is transmitted using Bluetooth channel to a mobile device and is converted to English text. Also, the authors of [44] developed an android

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application, which is used to send the message typed in Braille to the specified recipients' number. The project achieved full-duplex communication between mobile and PC using the glove. The downside of this glove is that the connections may come loose at any point and have to be secure because the communication gets truncated.

A similar project as described in [44] is, Virtual Talk for the deaf-blind uses a smart glove made of a unique nylon material, which is easier for the hand to move in it, also allergy-free, which everyone can wear. This glove is affixed with flex sensors, which change their resistance according to the degree of bend. When a user needs to communicate, he signs using the smart glove, and the sensor readings are converted to digital reading to represent an alphabet or word as programmed. This text can also be converted to audio cues, but it is still difficult to transmit a sentence or serial data. The present method is low-powered and affordable, but it is time-consuming. Also, for each person, using a flex sensor is different as the degree of bent for a particular alphabet differs from person to person; therefore, the smart glove has to be tuned for each person before using it. This glove does help a deaf-blind communicate to the other side but still faces the same problem to "hear" the reply.

Body Braille is a popular system where the deaf-blind are subjected to the braille characters on any part of their body like hand or back, which the user can read. This method ensures that a person can read Braille even if the person's hands are not free. Also, it enables multi-tasking by the user. In [44], project developers propose a method for learning how to read body braille for first-time users. In stage 1, the users are subjected to various patterns of micro-vibratory motors, and the user is asked to recognize them. Furthermore, the user is then subjected to identifying words, and this is the self-learning body braille. An application of Body Braille has been described in [45], where a deaf-blind person communicates with another deaf-blind using Skype and Body-Braille. The message is transmitted using Braille and converted to speech, which is transmitted over Skype, and the message from the other side over Skype is converted to Braille and read by the other person.

Working on the same lines of Body Braille, an SMS (Short Messaging Service) subsystem architecture is described in [44], where users can communicate with anyone using SMS services. The system works by first intimating the user using a control motor to communicate via SMS. The SMS text (electronic text) is received and is converted to a character array, this character array is converted to Braille, and the signals are given to the Body Braille cells worn by the user. According to the test results, the best outcome to Body Braille is recorded when the braille cells (micro-vibratory motors) are worn either on the arms or back. The characters are played one by one. If the user wants to reply, a Braille input machine can replicate the same process where Braille text is converted to text and sent using SMS. The only trouble with this system is that it is quite slow for the user; that is, understanding character by character takes up a lot of time.

6. Technology for the Mute

People who are typically mute (speech-disabled) may be the luckiest or the unluckiest of all. Disabilities that are not obvious to others can be a blessing or a curse for those with them. When it comes to communication, the esophagus, larynx, and vocal cords are among the body parts most commonly affected by mute individuals' difficulties. An intellectual handicap or the side effects of an illness or treatment might cause speech to be affected in some cases. Mute people often find themselves in uncomfortable situations because of their inability explain themselves, communicate emotions, or call for help. To help those who are mute, a slew of gadgets have been devised.

In the case of people who are unable to communicate verbally, the phrase "Augmentative or Alternate Communication" (AAC) refers to the use of technology to supplement communication. There are two ways to help persons who can't speak express themselves: one that doesn't use any tools, and the other that does it with the help of external aids. Unaided AAC relies on sign language, gestures, visualizations, and facial expressions, whereas aided AAC relies on technological, tactile, or visual means to convey or receive messages [46].

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Translators and interpreters can also be utilized to assist persons who are unable to talk. A common means of communication for those who are unable to speak is sign language. The issue here is that either they know sign language or they don't, which has been addressed by the sign converters. When communicating with someone who does not know sign language, it is necessary to employ modern methods.

For people who aren't familiar with sign language, a computerized system has been built in [47] to transform text into sign language. This is done by creating and saving a database table, which is utilized to correlate the input words and output the signed language using a 3D sign hand. Communication between a deaf person, a speechless person, and a person who is fluent in sign language is made possible through this method of communication. There are various factors that influence a person's ability to speak, including the pace of speech, the quality of sound, the accent, the language, and so on.

A video game project is being pushed as a way to normalize people's lives and improve their quality of life. Images are processed using Kinect (a 3D-stereo camera), and movements are utilized to communicate with the text being played [48]. You can navigate the game world entirely by using the basic gestures that have been pre-programmed for the game, without the need for any sort of vocal or auditory input or output. Players' confidence would be boosted by playing this game because it encourages social integration while instilling a sense of playfulness.

7. Technological and Research Challenges

In the previous sections, various technologies and devices are reviewed, which have been proposed or have been made commercially available. Different technological and research-based challenges exist, which are partially or not completely solved by the existing methods. In the following few paragraphs, these challenges are discussed, and in further sections, probable solutions to these problems and how they can be tackled or approached are given.

Challenges for Blind people

Blind people face major problems in unknown environments and uneven terrains like ramps, stairs, etc. In developing nations, visually challenged people may encounter rough landscapes, stone roads, potholes or damaged roads, intersecting driveways, street crossings, etc. These are places where many orientation devices fail to tell the user about when and how to cross the road; if it's a crossroad or a zebra crossing, it is difficult for the user to know when the traffic stops. Additionally, sometimes a dead-end, hilly area or bushes block the sounds of vehicles trees that cause good shadows to be produced.

Travelling has become an integral part of everyday lives now. It can be a short distance like intercity for personal or professional reason or longer distance like overseas etc. Visually impaired people may use auditory maps, public buses, or railways, which have become user-friendly even in developing nations. But the bus stations, subways, and railway stations where there is a higher chance of people running or crowding at ticket counters pose a severe threat to the safety of the visually challenged. Journeying using public transport also poses a problem of many stops before the traveler's desired destination has been reached. The subject in question also lags behind most of the population in realizing which bus number is approaching, number plates of cabs, nearby businesses, house numbers, and addresses.

The solutions described above include using RFID, GPS, tactile maps, etc. These maps lack details; they do not provide access to alternate routes and are not properly integrated with the real-time obstacle-avoiding system. They require a constant network connection, which is difficult to expect in a developing nation. These technologies are pretty expensive for their inclusion in the already existing devices.

Website accessibility and printed material accessibility are other challenges for the visually challenged, as already mentioned in the above sections. The existing solutions either put an extra burden on tactile perception or on the aural faculty on which the blind person already relies a lot. The pictures that are converted to raised dots do not give any information about depth, shadow, or colors. Also, graphs and pie chart, pictorial

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representation of data presents a challenge for the visually impaired. Braille literacy also plays a vital role in increasing literacy among the blind population. Some daily activities like reading digital data from everyday appliances and text data in pictures are nascent research areas that need to be worked upon to be commercially implemented.

Challenges for Blind-Deaf

The problems listed above are also problems faced by Blind-Deaf people. These people also have a more significant disadvantage of losing their aural faculty, making it challenging to identify people while conversing. Also, it is a cumbersome job when none of the past times like painting, music, or movies are inaccessible. They also have a limitation when textual or pictorial data have to be read or perceived. Other drawbacks include lack of access to the alarm and emergency information, orientation problems, and too much reliability on the tactile perception.

Challenges for Deaf or Deaf-Mute people

Singly impaired people with aural faculty or speech and hearing impairment usually have similar challenges. The challenges include exclusion from social interaction, access to music and movies completely, the gap between a generalization of a sign language and the various local sign languages which exist. The divergence while communication between the people who understand sign language and those who do not occur. Communication over phones has been solved up to a greater level. There is a need for the technological inclusion of such devices even in developing nations. The devices already in use by this community face a problem of time lag and time consumption in real-time. Also, for those who are just deaf, there is a problem of "deaf-voice". This issue has not been solved completely until now and poses a threat to the confidence and independence of the subject in question.

In daily lives, these people face problems in emergencies when either they are not able to perceive on time or sometimes when they cannot cause alarm to make their problem be recognized by people around. The translation of text-speech or sign-text/speech has been only explored for set sentences and words. This proves to be very time-consuming and exhausting. In developed nations, announcement systems and emergency messages are displayed textually at many public places, but in developing nations, there is still a long way to go.

Challenges for Researchers and Technologists

Firstly when technologists begin with an idea or designing an accessibility device, they are faced with the problem of sensory substitution. Sensory substitution has been described above and exerts a lot of pressure on other sensory organs, so its utilization can be done only to a particular extent. Also, many types of research have been carried out and implemented in the developed nation, which, when administered in developing nations, collapse under problems like lack of power supply, poor network connectivity, governmental policies, scarcity of distribution channels, and cost of the technology.

8. Discussion and Conclusion

The current world population is about 7 billion people, most of whom live in developing or less developed regions. Out of these 7 billion people, about 1 billion people are affected by some other disabilities. Most of them reside in lesser-developed nations. It is of utmost importance that measures and research work is carried out more with keeping its reach to developing countries accessible. Also, design factors like cost, weight, and look should not be compromised. Technological factors like efficient power supply safety features for the user should be user-friendly, and ample testing should be done with subjects the device is targeted.

From the devices discussed and reviewed in the previous section, it is clear that not much research and work has been done in the field of multiple disabilities. People who are multiply disabled are constantly forced to use various devices or technologies at the same time to cater to their needs. Also, many customized devices are available, but when we talk in a broader sense, people in developing nations who are multiply-disabled cannot afford customized technology for their use. This inhibits their social life, and they become a liability for a country, which prevents the nation from growing and flourishing.

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The authors have been developing a device that caters to the need of multiply disabled people, keeping the focus on a generalized design for such a population in the developing nation. The customization process can be avoided in this device, as many individual detachable devices will be prototyped, which can be easily chosen and attached to either a wheelchair or further on a portable station. This device would cater to the user's communication, orientation, and assistive daily living. Features like a portable health monitoring system, a social network design, and multiple channels for communication with safe electrical system design will be incorporated. This device would be well equipped with means by which users will access all the resources stress-free.

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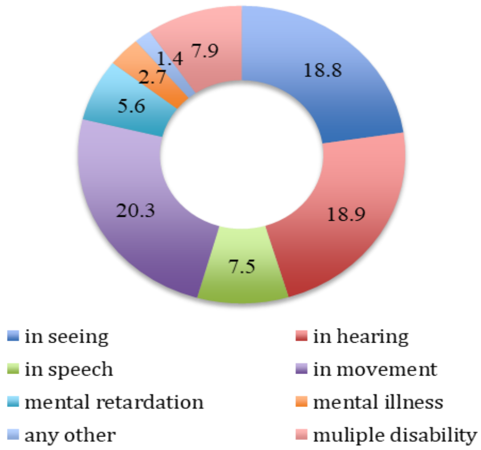

Figure 1. The proportion of Disabled population by type of Disability, India Census: 2011.