CHAPTER

Emerging Assistive Technologies and Challenges Encountered

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To Cite This Chapter:
Demiral, D., G. (2023). Emerging Assistive Technologies and Challenges Encountered. In M.H. Calp & R. Butuner (Eds.), *Current Studies in Technology, Innovation and Entrepreneurship (pp. 1–21). ISRES Publishing.*

Introduction

According to the World Health Organization (WHO) and its International Classification of Functioning Disability and Health (ICF), disability is an umbrella term encompassing impairments, activity limitations and participation restrictions (WHO, 2001, p. 213). The WHO considers that disability as the result of the interactions between health conditions (such as diseases, disorders, and injuries) and various contextual factors. Contextual factors may include external environmental factors such as legal attitudes, social attitudes, climate etc. as well as internal personal factors like gender, age, education, behavior pattern, and so forth and also other factors that influence how a person experiences disability (WHO, 2002, p. 10). Disability should not be viewed as a clear-cut situation; instead, it exists on a spectrum defined by the interaction between the individual and their environment. As a result, whether a particular condition qualifies as a disability or not hinges on the environmental and societal obstacles that an individual, with their unique characteristics, must confront (Nierling et al., 2018, p. 11). The fact that disability is not only health-based but also has many causes makes the definition of "disability" multidimensional and complex.

As stated by the World Health Organization, 15% of the world's population, approximately 190 million people, have different types of disabilities and 2-4% of the total population have major functional difficulties. It is predicted that disability rates will increase due to the aging of the world population and the emergence of chronic diseases (WHO & World Bank, 2011, p. 44). Between 2020 and 2030, the global population of individuals aged 60 and above is projected to increase from 901 million to 1.4 billion. By 2050, this number is anticipated to double to nearly 2.1 billion. Projections suggest that by 2050, the population of individuals aged 80 and above will reach 434 million, which is three times the current number of people in that age group. While many older individuals will enjoy good health, the prevalence of disability is also expected to rise proportionally, posing a significant challenge to healthcare systems (Millana et al., 2020, p. 2).

Disability encompasses a diverse range of people. Some are born with it, while others result from accidents, injuries, or chronic illnesses. Additionally, disability that occurs in the later stages of life is among the most common. People's health needs and the tools they need to use may vary depending on their disability. Since there are various restrictions, a tailor-made healthcare service may be required. Since this situation can sometimes lead to high health needs, the way disability is addressed has begun to shift from a medical approach to an approach that increases individuals' well-being and functionality (Scholz, 2015, p. 1). Assistive devices and applications serve as support for disabled people to survive, become productive individuals in society, and contribute to their social, cultural and economic lives. Many traditional mechanical devices are useful for daily activities and are also preferred by some disabled people. However, everyone's disability and living conditions differ. Many people may have more than one disability at different levels and therefore need different levels of care. On the other hand, the social and economic situation of these people, the extent to which they need to participate in business and education life, their life habits, expectations and demands may also differ. In addition, with the diversity and advancement of technology, classical and traditional devices have become insufficient for disabled individuals to become productive in society. With developing technology, researchers and entrepreneurs have started to search for more technological assistive devices suitable for disabled individuals.

According to WHO (2022, p. 6) "an assistive product is any external product (including devices, equipment, instruments or software), especially produced or generally available, with the primary purpose of maintaining or improving an individual's functioning and independence, thereby promoting their well-being. Assistive products are also used to prevent impairments and secondary health conditions. Similarly, the definition of an assistive product by ISO 9999:2011 is "Any product (including devices, equipment, instruments, and software), specially produced or generally available, used by or for persons with disabilities for participation; to protect, support, train, measure, or substitute for body functions/structures and activities; or to prevent impairments, activity limitations, or participation restrictions" (Scholz, 2015, p. 4). Assistive products include physical items like wheelchairs, glasses, hearing aids, dentures, walking aids, etc. They also encompass software and applications in digital form, which strengthen interpersonal communication, provide quick access to information, support education and training, etc. In conclusion, an assistive product serves as a bridge between an individual and the life they aspire to lead. Technology lies behind the emergence of assistive products. That we can call "Assistive Technology (AT)". AT provide the opportunity for elderly individuals, disabled people, and people with medical conditions or injuries to live an independent life by making their lives easier. AT plays a major role in enabling individuals to be more productive, receive education, and participate in the workforce and society. Today's technological developments have also accelerated the development of ATs. AT products integrated with today's most up-to-date technologies such as Artificial Intelligence (AI), sensor and wearable technology, IoT, virtual-augmented and mixed reality, robotics, and brain-computer

interface have gradually begun to take a place in the lives of disabled individuals.

The Aim of the Research

This study encompasses a conceptual exploration AT, aiming to shed light on the extent of technological advancements by providing examples of some products, services, and applications. Recognizing the anticipated increase in the need for AT in the coming years, the research also aims to raise awareness within society and keep individuals informed about the development of AT. Although having access to AT is considered a "human right" for people with disabilities, the study addresses challenges related to AT, emphasizing the need to resolve these issues. The paper discusses these challenges and provides solutions as well.

Assistive Technology Concept

Technology has the effect of making life easier, speeding up work, and providing all kinds of access to information. The technology that surrounds us is an indispensable part of our daily lives. While having technology is important, it is equally crucial to choose the right technology for the activities we want and need. What matters most is the individual's use of enabling technologies, their experience, and satisfaction level. At this point, having AT becomes very important, as it has a facilitating effect on the lives of disabled individuals.

The concept of AT has been extensively employed across various domains over the years. One of the initial official definitions of AT was enshrined in the Technology-Related Assistance for Individuals with Disabilities Act. This legislation, initially enacted in 1988, reauthorized in 1994, and reintroduced in 1998 (Golden, 2011), outlines AT as encompassing any item, equipment, or customized product system, whether commercially obtained or modified, aimed at enhancing, maintaining, or improving the functional capabilities of individuals with disabilities. Furthermore, the act underscores the significance of AT services, denoting any service directly aiding an individual with a disability in the selection, acquisition, or utilization of an AT device. AT isn't solely designed to enhance capabilities for individuals with disabilities but can also assist others, such as family members and caregivers, in performing daily tasks associated with instrumental activities of daily living, including education, work, and social and cultural engagements (Alper & Raharinirina, 2006, p. 47-48).

According to the WHO organization, AT is assistive items, services and systems used to maintain or restore an individual's functionality and increase their level of well-being. The Assistive Technology Industry Association provides a definition for AT that products and services as any object, device, piece of hardware, or software designed to aid individuals dealing with various forms of disabilities. AT includes a range of services, products, methods, approaches, and techniques designed to reduce or remove the barriers and constraints faced by individuals with disabilities or impairments (Fall et al., 2017, p. 967). AT enables individuals to do jobs that they cannot do or make them easier to do. In this sense, AT has the status of special products that help disabled people to compensate for the freedoms they have lost or feel deficient in, and can include any product, device, application or software. By making the lives of disabled individuals easier and safer, AT can reduce not only their freedom but also their need for others. AT offers individuals the opportunity to be active in education, business and social environments with ease and self-confidence. According to Aqel et al (2019, p. 17) without AT, individuals with disabilities are excluded from society, isolated and condemned to poverty. This increases the negative impact of disability on families and society. In fact, according to Wolbring (2011, p. 611) there are still debates regarding whether a device that goes beyond a 'normal' human is considered an AT within the definition of AT's.

As per the 2018 report from the WHO over one billion people worldwide require AT, yet only one out of every ten individuals have access to the necessary products. By 2030, this substantial number is expected to double, reaching the threshold of two billion. According to WHO (2022) for a more detailed breakdown of the current global AT requirements. This includes 970 million individuals in need of eyeglasses and low vision aids, 75 million who require wheelchairs, 150 million in need of mobility aids, 35 million seeking prostheses and orthoses, 94 million who could benefit from hearing aids, and 150 million individuals requiring cognitive aids (Aqel et. al., 2019, p. 16).

AT has become a growing field with the advancement of digital technology and the constant change of needs. Especially with the aging of the world population, the interest in AT has increased both for users and has become an area of opportunity for businesses (WHO, 2022). AT can support individuals in accessing their human rights. With the help of AT people with disabilities can achieve the fundamental human right of participating in all aspects of society. The development of technology has changed everyone's life, but it is especially important for disabled individuals. Because it often helps disabled people find and maintain employment. According to the National Disability Authority (2005) report, 85% of disabilities are acquired during working life. When individuals with disabilities cannot access such technologies, employment and career advancement are compromised (DFI, 2016).

AT, regardless of device complexity, can compensate for sensory, physical/mobility, and cognitive impairments and aims to maintain or enhance individuals' functionality, helping them achieve a better quality of life (Lancioni & Singh, 2014; Boucher, 2018). There are a wide variety of Low Tech or High tech ATs available (Marino et al., 2006, p. 21). These products vary in technological complexity and detail. Low-tech products are equipment or tools that are more affordable, do not require much training and preparation to use, and have simple mechanical features. Large print, walkers, canes, etc. may be in this category. High-tech ATs, on the other hand, are computer-based, costly products that have complex electronic components and require training before use. Devices that produce private speech, shoes that recognize obstacles and determine routes, home automation systems, etc. High-tech devices have diversified, especially with the development of mobile phones and software.

Literature Review

There are many areas where AT are used. AT has a wide range of uses in autism, emotional and behavioral disorders, intellectual, physical, speech and learning disabilities, traumatic brain injuries, blind and vision impaired, deaf and hearing problems, and the elderly. Many studies have been conducted in the literature related to AT. These include research focusing on specific disabilities, as well as studies that address methodological approaches or have a conceptual nature. The following mentioned studies encompass only those that specifically revolve around the development of products, services, or applications related to AT and those addressing the challenges associated with AT.

AT are very helpful tools in the rehabilitation process for individuals with autism. AT can play an active role in improving social, functional and communication skills and repetitive behaviors in individuals with autism. Chen et al (2016); Parsons (2016); Law et al (2018); Hussain et al (2016); Kandalaft et al (2013) have enriched their contributions to individuals with autism with examples of AT products such as augmented and Virtual Reality (VR), mobile learning and educational entertainment. There are many ATs that have been developed for individuals who are blind or have limited vision so that they can find their way, go where they want, and know what products and services they may need. With the development of mobile technology, many applications are available in addition to the tools used. Tapu et al (2014); Manjari et al (2020) researched wearable products used for visually impaired individuals to navigate outdoors. By developing an obstacle

avoidance system, Zahn & Khan (2022) sets an example of technologies that provide greater independence for the visually impaired. Xiao et al (2021) developed a guide robot dog model that helps visually impaired people find their way. Júnior et al (2019) have presented a framework that uses machine learning and computer vision techniques to use an IoT device to identify objects, measure distances, and transmit information to a visually impaired individual. Chang et al (2019) developed a deep learning-based wearable drug recognition system. Zainuddin et al (2010) conducted an augmented reality application called AR-Book for the use of hearing-impaired students. Lin et al (2018) and Chern et al (2017) propose a mobile phone-based hearing aid system (SmartHear) that uses wireless technologies for those with hearing loss. Thinh et al (2017) discuss a robot developed to translate spoken language texts into sign languages. Rashid et al (2017) and Sai et al (2017) designed a system to control the devices in the house by using voice commands and sensor technology to turn on and off some devices in the house (such as opening and closing doors). Burleson et al (2015) introduced DRESS, a computer vision system that facilitates the dressing process for Dementia patients and will help the dressing process without a caregiver. VR technology can also be successful in recalling old memories. A study conducted by Benoit et al (2015) suggests that VR can assist in memory recall in elderly individuals. Scholz (2015) included examples of AT developed for individuals with visual, hearing, cognitive, communication and motor disabilities.

Das et al (2017) examined the IoT approaches recommended and designed especially for elderly individuals and the challenges related to IoT use. Cruz et al (2016) conducted research in private and public rehab centers to determine the difficulties experienced in the use of AT by therapists working with disabled people and in accessing these technologies. In their research, Steel et al (2016) discussed challenges to AT use at the level of interaction between practitioners and consumers, and challenges at the level of markets and policies. 3D printing, which can be considered as one of the AT products, has a great place especially in rehabilitation and physical therapy. In this sense, Mcdonald et al (2016) conducted a study to identify the opportunities and obstacles of 3D printing in the field of physical therapy. Demirok et al (2019) and Kutlu et al (2018) conducted research to determine the attitudes of special education teachers towards the use of AT. Contepomi (2019) discussed the various opportunities and obstacles to providing adequate access to AT in Argentina.

Emerging Assistive Technologies

Today, we observe widespread access to innovative high-tech solutions across various fields. According to WHO (2022) report, while future innovative applications may reach an advanced level, it is noted that the majority of people with disabilities will have simpler needs for assistive products. However, with the continuous advancement of technology, the utilization of high-tech solutions is likely to become prevalent in various professions, benefiting people across different walks of life. Consequently, individuals will need to adapt to these innovative applications in the near future. People with disabilities, in particular, will require high-tech assistive products that can seamlessly adapt to these evolving technologies.

Advanced sensors, AI, and IoT are propelling the transformation of traditional AT into ‘smart’ assistive products. Sensor technology is leveraged in many smart products such as walking aids and wheelchairs that incorporate lightweight detection sensors. Additionally, there are numerous assistive products that result from the convergence of multiple technologies. For example, medication dispensers are connected to IoT/sensors or integrated with AI systems for medication management. Moreover, there are both wearable (smart clothing, lenses, wristbands, watches) and non-wearable devices (smart carpets and mirrors) that utilize sensors, AI, machine learning, IoT, and cloud

connectivity for monitoring health and emotions.

The report prepared by WIPO (2021) mentions emerging technologies in the AT field. These can be; AI, IoT, brain-computer interfaces, sensor technology, robotics, advances in computing, VR/augmented reality and connectivity; additive manufacturing; new materials and Autonomous vehicles. Although the products, services and applications given below are classified according to the technologies used, it should be remembered that the examples mentioned do not only use the specified technology. Many ATs have devices produced using more than one technology. Therefore, for example, products promoted under AI technology can contain sensor technology, IoT, Robotics etc.

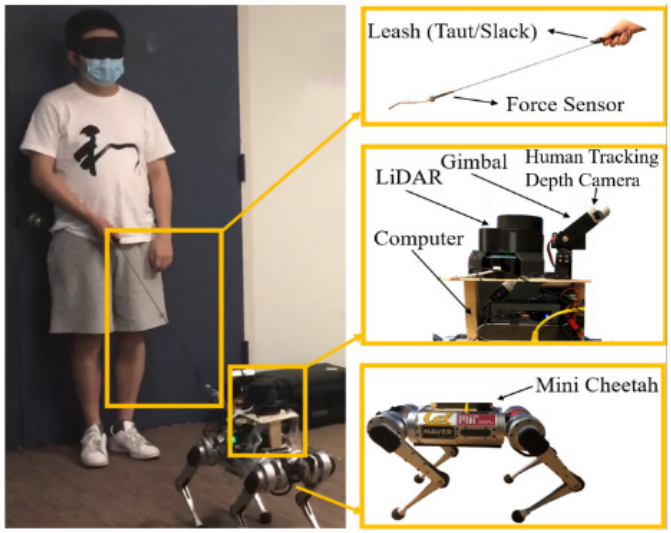
Robotic Assistive Technologies

One of the fastest-developing technology is robotics which also has a significant impact on the socio-economics field. Robotic applications are finding their place in healthcare, education, and social environments, serving a wide range of purposes. These include caring for and educating children with autism, as well as children and individuals with physical disabilities. Additionally, robots provide companionship for older persons with dementia and are utilized for rehabilitation and training (Bemelmans et al., 2015; Bedaf et al., 2017). Among the most promising developments are assistive robots, autonomous systems capable of 'living' with individuals and assisting in all daily life activities such as dressing, toileting, eating, interpersonal interaction, and more (Huijnen et al., 2019). These robots provide physical assistance, including robotic wheelchairs, and social assistance robots designed to address socio-emotional needs, are commonly used in elderly and cognitively impaired populations. Social assistance robots are equipped with a social interface to facilitate interaction with users (Yu, et al., 2022, p. 2). With the elderly population steadily increasing and projected to double by 2050, reaching a level of 2.1 billion, the demand for these robots is expected to grow even further.

Instead of traditional sensor-equipped canes, a robot called **CANINE,** functions as a cane-like mobile assistant, especially for the elderly and individuals with balance and visual impairments. By autonomously following the user, it allows them to maintain a coordinated and attentive-free movement (Stramel et al., 2019, p. 4139-4140). CANINE is a robotic cane connected to a mobile robot that automatically tracks and moves alongside a walking individual, essentially serving as a type of mobile assistant. **KASPAR** is a robotic assistant designed as a social companion for children with autism, is a child-sized humanoid robot. It aims to support teachers and parents in helping children with autism overcome the challenges they face in socializing and communicating with others. KASPAR facilitate therapy games with children of autism and communication difficulties, and it helps identify their emotions and stress levels during these games. With Kaspar, children with autism play therapy games, and through various smart sensors, it tracks eye movements, facial expressions, sound, and posture. Research shows that Kaspar encourages collaboration among children, extends their attention spans, promotes social interaction among children, and helps them learn about body parts (Wainer et al., 2014). Guide dogs are of vital importance for helping visually impaired individuals navigate their surroundings. However, raising and caring for guide dogs can be quite challenging for disabled individuals. Today, there are guide dog robots developed under different names. One of these robots has been created at the University of Berkeley. **The Mini Cheetah** is equipped with Lidar technology for environmental perception and a camera to detect the position of the person it is guiding. A visually impaired individual uses a special leash to understand which direction the robot dog is leading them. The leash, with one end attached to the robot dog, is equipped with sensors that can measure its own tension. This allows the robot dog to determine whether the leash is taut or loose. When robot dogs need to change direction during movement, they first take a few steps back to loosen the leash, signaling to the visually impaired

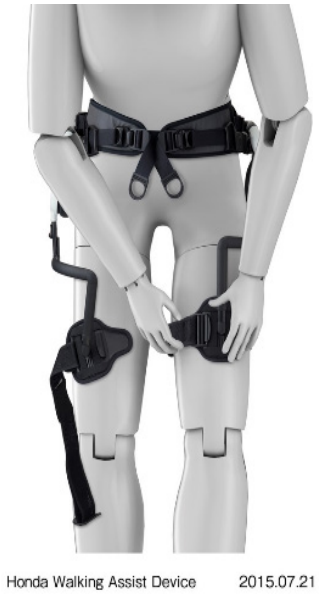
person that they need to stop. After the robot determines the correct direction, it resumes moving, and the visually impaired person starts moving again when they sense the leash has tightened (Xiao et al., 2021).

Figure 1. *The Mini Cheetah*



iBOT is a specialized wheelchair device designed for individuals with limited mobility or who use a wheelchair. It can go up and down stairs with its self-balancing technology. It is a very useful assistive device for the physically disabled with its ability to convert from four wheels to two wheels, height adjustment and climbing stairs. Similarly, **TopChair-S and Scewo** are other assistive devices that use robotic and sensor technologies. **Honda Walking Assist (HWA)** is an exoskeleton type robot, helps individuals living with walking difficulties. The control computer initiates motor activation using information acquired from hip angle sensors while walking. This is done to enhance the synchronization of each leg's lift-off and forward extension, thereby facilitating a more balanced and smoother gait with an increased stride length for easier walking. Studies show that patients using HWA achieve significant improvement in their walking functions with long-term use.

Figure 2. *Honda Walking Assist*



Artificial Intelligence Based Assistive Technology

The term "AI" was introduced by John McCarthy, regarded as the pioneer of AI, in 1956, during the first AI conference held at Dartmouth College. McCarthy's definition characterizes AI as the science and engineering focused on creating intelligent machines, particularly intelligent computer programs. AI is used in many areas today. In health, energy, telecommunications, vehicles, telephones, etc. AI is also used in many of the high-level AT developed for the disabled. AI technique is widely used to enable or facilitate the daily activities of people with vision, speech, hearing, cognitive disorders and movement disorders. Other AI technologies such as machine learning, 3D printing, deep learning, natural language processing, artificial neural networks have high potential in the development of AT tools. The recent growth in the field of AI can be attributed to deep learning, a technique that enables computers to perform complex human-like tasks such as speech recognition, image analysis, and object recognition (WIPO, 2021).

Sensor technology is not a new field, but there have been significant improvements in the last few years, allowing them to advance various technological fields. Advances in sensor technology have also enabled developments in wearable technology and the internet of things. In this section, sensor technology and AI applications are exemplified together.

OrCam MyEye is a good example of using AI technology to assist people with visually impaired disabilities. A wearable, voice-activated solution for individuals with visual impairments. It provides the ability to instantly read text from any book or screen, effortlessly recognize the faces of family and friends, and accurately identify various products, all in real-time communication with the user. Similarly, wearable devices such as **Horus, eSight** and **Aira** are offered to visually impaired individuals. These devices have the ability to identify what users are looking at using deep learning and object recognition methods.

Figure 3. *OrCAM, Horus and Aira*



Source: (Bigumu, 2023)

The AI-supported **WeWalk** smart cane, designed for the visually impaired by YGA (Young Guru Academy) and Vestel engineers in Turkey, has features aimed at enhancing individuals' mobility. WeWalk alerts the individual by vibrating about obstacles that might go unnoticed. By integrating with a smartphone, it provides voice feedback for finding the current location, navigating to new locations, and allows control over the device. It has the capability to integrate with mobile applications, enabling self-improvement features. A new project called **Feeling Fireworks** aims to make people who are blind or have low vision 'feel' fireworks. The project, offers a tactile fireworks show in which fountains are transferred to a flexible screen. Users extend their hands towards the screen. Kinect placed near the screen detects the user and the user feels tactile fireworks that resemble real fireworks exploding in the sky. Different heads produce different parts of the firework. Three caps produce the explosion effect, while another cap produces the crackling sound of a firework. Another title reveals the floral image created by fireworks (Reusser et al., 2017, p. 65).

Figure 4. *Feeling Fireworks*



Feel The View, developed for visually impaired individuals, is mounted on the car window, allowing them to feel the view. A camera is used to capture the view. It then converts the photo into a high-contrast grayscale image. With 225 different intensity levels, each shade of gray gives unique vibrations that enable the visually impaired passenger to feel what is outside by touch. There is also a voice assistant that provides detailed scene descriptions, which can be connected to the vehicle's audio system. The system is described on the Ford Europe blog as a smart window for the visually impaired (Bigumigu, 2023).

Figure 5. *Feel The View*



Advanced sensors and AI have succeeded in making traditional AT 'smart.' Both of these technologies are utilized in many assistive devices. Machine learning, a component of AI, is also used to develop smart glasses that detect distances between the user and objects in the environment to assist with navigation. The **Envision Glasses,** a smart eyewear for the visually impaired, can scan and read aloud everything, including handwritten text; it can recognize human faces, objects, and outdoor scenes. To support reading in over 60 languages, the Envision Glasses utilize AI. The device can also provide detailed descriptions of outdoor scenes to the user. It enables private and secure video calls with trusted users. Additional features include color detection, light detection, object recognition, and face recognition. With the object recognition feature, users can keep track of their belongings and find them whenever needed (Envision Glasses, 2023). **Liftware** is an electronic fork and spoon designed for individuals with Parkinson's disease and other movement disorders. Regardless of how much the hand moves while eating, it ensures that the food does not spill with its stabilizing head. **Carbonhand** stands as a groundbreaking assistance tool, restoring empowerment to individuals with impaired hand function (Bioserve, 2023). Utilizing pressure sensors and cutting-edge technology, this glove provides additional strength when the user's natural muscle strength falls short. Functioning as a beneficial aid, Carbonhand takes the shape of a grip-enhancing glove equipped with pressure sensors on the fingers, capable of identifying moments when the user requires additional support. **Neural Sleeve** leg, a wearable technology product brought to life with CIONIC's AI supported technology; It promises independence for those who have movement restrictions such as sclerosis, stroke, cerebral palsy. It uses AI and functional electrical stimulation through electrodes to promote leg movement and smoother walking (Neural Sleeve, 2023). A different protective headgear called **Hear Gear** was developed in order to create an egalitarian environment in sports by helping sports people with hearing problems. The protective headgear which has a special technology, absorbs impacts while also allowing people with hearing problems to hear without any problems with its built-in hearing implants.

Individuals who used hearing aids during sports could not hear due to the headgear. This problem is overcome with HearGear (Bigumu, 2023). For visually impaired people, walking outside can be stressful and unsafe, especially in big cities. Passing among people in a crowded place or moving depending on someone or a living creature (guide dog) can limit a person. Biped guides the person with intuitive feedback for the visually impaired; aims to eliminate this problem. The 3D infrared camera located in front of the AI-supported device placed on the user's shoulder can take images at a 170-degree angle. AI-based software notifies the user of fixed or moving objects in the environment a few seconds in advance through spatial sounds.

Figure 6. *Carbonhand and Neural Sleeve*



Wearable Assistive Technology

The effects and applications of wearable technology are very extensive. It can impact fields such as healthcare, medicine, fitness, aging, disability, education, transportation, business, finance, gaming, and music. In each of these areas, the goal of wearable technologies is to seamlessly integrate functional, portable electronics and computers into individuals' daily lives. One of the most significant features of wearable technology is the ability to connect to the internet and exchange data between the device and the network. This capability for both sending and receiving data is facilitated in wearable technology through the IoT. Today, wearable technologies stand out as the widespread use of augmented reality technologies. In this sense, many companies have developed wearable technologies in the form of glasses, headgear or helmets, watches, t-shirts, shoes and even jewelry.

One of the fundamental factors that make life difficult for individuals with hearing impairments is that not everyone knows sign language. The smart glove **Sign-IO,** which can convert sign language into spoken speech, reduces this barrier through sensors on each finger that translate finger movements into letters. This way, when a hearing-impaired user communicates using sign language, their finger movements are measured accurately, and they are connected to a mobile application via Bluetooth to enable the other party to understand them. **SilentWakeUp** is able to wake up users who are hearing impaired or have difficulty hearing. This wearable watch, measuring 1 x 3 x 5 cm, adheres to the user's body through medical-grade adhesive pads. The system connects to a smartphone application via Bluetooth. Users can set their wake-up time on the smartphone. SilentWakeUp starts vibrating gently 10 minutes before the alarm time. Then, the vibrations gradually intensify. Depending on how deeply the user is asleep, the system can be adjusted to three different vibration levels. **The Sound Shirt** is a wearable technology product developed specifically to enhance the auditory experience for individuals with hearing impairments. It translates sounds into vibrations for the hearing-impaired. The software integrated into the Sound Shirt is capable of translating 8 different types of sounds, including bass, cello, horn, and percussion. Data is sent to

the garment via a wireless system, and the intensity of the music is also detected, then converted into vibrations by 16 micro actuators on the garment. **Sunu Band** is the first smart bracelet that enhances mobility and independence for visually impaired individuals using Sunu-ultrasonic wearable technology. With this device, disabled individuals can feel and navigate their surroundings without physical contact. It provides notifications to the user via vibrations when it detects an object or a person at a distance of approximately 4.5 meters. **Vizorro** is a compact wearable laser navigation device that measures the distance to any obstacle pointed by the user. This unique device employs the principle of sensory extension, allowing blind individuals to sense the distance to various obstacles in their surroundings. Vizorro can be directed in different directions and aids the user in scanning their environment for obstacles (Alabi & Mutula, 2020, p. 14).

Figure 7. *The Sound Shirt*



Google Glass is a wearable assistive device that can help autistic children analyze their emotional states. With the use of specialized applications or software, the device can introduce facial expressions, emotional tones, and other social cues to assist autistic individuals in improving their interaction skills. The device can also control sound and light settings through specialized software and sensors to create a comfortable environment for autistic individuals. The system recognizes seven facial expressions happiness, anger, surprise, sadness, fear, disgust, and contempt (Haber et al., 2020, p. 49). **Dot** is the world's first Braille smartwatch. Dot assists visually impaired individuals in tasks such as accessing messages, sending tweets, using social media, and sending email.

Figure 8. *Dot*



Assistive Software and Applications

Seeing AI is an AI application developed by Microsoft, specifically designed for individuals with visual impairments. . It is a free application that encompasses various functions, including short text, document, product, person, scene, currency, light, color, and handwriting recognition. Some of its features include reading text captured by the camera, using beep sounds to guide users to products, scanning product barcodes, predicting people's ages, genders, and facial expressions, saving people's faces, recognizing paper currency, reading handwriting such as on greeting cards, describing images in Mail, Photos, Twitter, and more. This application aims to provide convenience for individuals with visual impairments, offering features such as listening to descriptions of stored photos on the device and recognizing people, along with guessing the age and

emotional state of strangers (Seeing AI, 2023). **Be My Eyes** is an application where blind and sighted volunteers are brought together. This application provides vision for the visually impaired by using the power of technology and human relations. Finding lost items, a problem with the computer while grocery shopping, reading labels, using different items, etc. can be used for aid. In other words, their work is done without having to wait until a sighted person arrives. **The LookTel** application, developed for the visually impaired, provides the opportunity to scan and instantly recognize related with money transactions. Users point their mobile phones at the bill and take a photo of it. They can hear the total amount. **SoundPrint** is a mobile application specifically developed for individuals with hearing impairments. This app helps users assess and share the noise levels in restaurants, bars, and other public venues. SoundPrint evaluates the noise levels at various locations, assists in finding quiet places, and facilitates the creation of community-based information by allowing users to share their assessments of venues with others. Another major problem faced by individuals who use wheelchairs is the suitability of the places they intend to visit for their own conditions. The **Wheelmap** application marks the accessibility of heavily frequented places for people with disabilities on the map. This way, individuals with disabilities can be informed in advance about the accessibility of the places they plan to visit. **Dragon Naturally Speaking** is a speech recognition software that uses speech to text, allowing users to dictate rather than type. It is an application that especially assists individuals with visual impairments in tasks like document preparation, email usage, and computer control. It allows users to communicate by speaking without the need for a keyboard or mouse, especially when creating text documents or using their computers. **Talkitt** is an application developed for individuals who have speech and language problems and cannot communicate with others. The application can learn the user's speech and language and translate accordingly. This app, which translates incomprehensible pronunciations into understandable speech, helps people with cerebral palsy, ALS and other speech disabilities. The project called **Facing Emotions** was developed with a new programming language. Thanks to this, the phone, which can be attached to the human body with an electronic device, converts facial expressions and emotions into sound with its rear camera using facial recognition technology and transmits it to the headset worn by the visually impaired person. With this application, which can analyze the voice according to the emotion people feel to the other party at that moment, it is a big step towards eliminating some of the obstacles that may arise for disabled individuals. **VizWiz, Orbit, SayText** are some of the many applications developed for disabled people.

Virtual / Augmented / Mixed Reality Based Assistive Technology

VR is interactive simulations in which computer-created three-dimensional environments are experienced with more than one sense (Muscott & Gifford, 1994, p. 417). Since the 1990s, VR applications have been the subject of educational studies for special needs groups. In these years, researchers began to use virtual environments to teach people how to use wheelchairs (Inman et al., 1994). Individuals with special needs have limited access to the outside world. They can gain the experience of acquiring these skills in virtual environments, especially in situations where physical requirements are required (crossing the street, operating a stove or oven, cooking, etc.). Virtual environments also enable experiencing expensive, dangerous and difficult conditions (Kandalaft et al., 2013, p. 35; Novak, 2009, p. 28). VR technology provides permanent learning by giving users the feeling of being there in the user's brain with the virtual environment experience it provides and allowing it to be recorded as a memory experienced in the mind (Bailey et al., 2012, p. 24). VR technologies also create great opportunities for disabled people with the experience they provide.

Navigation and reading are two of the most significant challenges faced by individuals with visual impairments. Warning signs and location markers in both indoor

and outdoor environments can pose difficulties for people with disabilities (Sezgin, 2020, p. 91). **Microsoft HoloLens,** is an intelligent mixed reality headset powered by AI and machine learning. Microsoft HoloLens offers a sign-reading application designed to provide a solution for individuals with visual impairments. The device utilizes cameras and audio sensors to obtain real-time information, processing it to relay the locations of surrounding individuals to the user's ear within second. At Aalto University in Finland, orientation for wheelchair-using students on campus is being conducted using **Oculus Rift VR** glasses. The integration of VR hardware into wheelchairs has been observed to accelerate the adaptation of disabled students to the school (Lawther, 2016). The VR simulator called **VADIA** assists young individuals with autism in developing independent behaviors and improving their driving skills for autistic individuals. **Eye Play the Piano** can be commanded by eye movements to the digital piano presented in the VR environment and enables the use of the piano for physically disabled individuals (Eye Play The Piano, 2023.)

Figure 9. *Hololens and Eye Play The Piano*



DeepStream VR is a company specialized in creating immersive virtual worlds to help alleviate pain. They offer compelling VR experiences that enhance the quality of life for patients. They utilize VR technology in various areas, including physical and cognitive rehabilitation, phobia treatment, improving social skills, stress reduction, meditation practices, and entertainment for individuals with disabilities. VR technology has opened up many possibilities to improve the lives of patients and individuals with different needs. Mixed reality creates a new environment by using both virtual and augmented realities. The key distinction between mixed reality and augmented reality is that in mixed reality, users can interact with virtual objects and data in real-time. **Microsoft Mesh**, a mixed reality platform, integrates with various devices such as smartphones, computers, tablets, VR headsets, and augmented reality glasses to offer users a holographic experience. This allows people to come together in virtual environments regardless of time and location. Microsoft Mesh provides users with various advantages, including the ability to work with 3D models in real-time and interact with other users by creating holograms or avatars (Papuççiyan, 2021).

Challenges and Solutions of Assistive Technologies

Evidence presented by different organizations shows that people with disabilities experience discrimination and inclusion problems. ATs are considered as a medical condition that needs to be managed or treated for disability, to maintain and increase the individual's independence, to participate in society. However, in the last few years, some technological advances, defined as accessible technology, have addressed disability not only as a functional limitation but also as a barrier to social integration. In this respect, technology is seen as a factor to facilitate and normalize the lives of individuals with

disabilities, especially in terms of reducing certain barriers in the field of employment (Kritikos, 2018, p. 4).

Today, AT undoubtedly serves important purposes for many disabled individuals. But unfortunately, it also faces many difficulties. We can list the difficulties such as accessibility, costs, designs, usage levels, countries' policies, and users not being aware of it or not knowing how to use it.

With the regulation made on 19 February 2014 in the Law on Disabled Persons, definitions regarding accessibility are also included. In article 3 of the law; "Accessibility; buildings, open spaces, transportation and information services, and information and communication technology should be accessible and usable by disabled people safely and independently". Accessibility refers to the fair and equal distribution of resources so that individuals have equal opportunities to access appropriate products and services for their needs. In order to access products and services, accessibility to information, transportation and communication is required (Kritikos, 2018). According to this concept, disabled people should be able to leave their homes without needing anyone else, go wherever they want, and use the products and services they want easily and without needing anyone else. Physical and architectural measures need to be taken and adapted to developing AT in order to ensure participation in city life. Making the necessary design arrangements at the accessibility level so that disabled individuals can continue their daily life activities such as living-resting-entertaining and shopping like healthy individuals, should be considered important in solving the restrictions of disabled individuals from social life. Public policies developed especially for disabled individuals and environmental accessibility need to be integrated with each other. The development and adaptation of institutional places such as markets, post offices, hospitals, cities, cinemas, roads, cars and all the things we need on a daily basis around us in accordance with the use cases of developing AT will become even more important in the future. AT should be adapted to the needs of disabled people and be easily accessible. Solutions that are only offered in certain regions contradict the principle of accessibility. Various elements, such as an individual's functional capacity, awareness level, socioeconomic standing, living circumstances, and engagement with their surroundings, play a role in determining their requirements for and availability of AT. Comprehensive comprehension of the associated needs within the populace and recognizing the primary obstacles to obtaining assistive products are crucial initial prerequisites for enhancing accessibility (WHO, 2022, p. 24).

Some AT is much more expensive than individuals can afford. Although some of them are suitable, individuals do not have the power to resist them. Purchasing the AT needs of disabled individuals may vary depending on the health policies of the countries. While some countries cover some of the ATs depending on the disability, some do not cover any of them. ATs must be obtained by individuals with disabilities, especially since they are not included in health insurance or other reimbursement mechanisms. And this is often quite expensive, making it impossible for everyone to use it. According to WHO (2018, p. 6), it is estimated that 1 million people in the world need AT. However, only 1 in 10 people can access AT products. It is estimated that this need will double in 2050 with the aging of the population and the increase in non-communicable diseases. In anticipation of the great need, WHA (World Health Assembly) called on member states and WHO to improve access to AT as part of universal health coverage. It is very important to define AT as a medical device or for general use. If the AT has a medical label, the social system can pay for the use of the disabled individual, whereas when the AT is defined for general needs, the user has to pay the cost (Kylberg et al., 2015, p. 63). This situation confronts disabled individuals with a great difficulty.

Data is needed to fully determine the AT need in a country. There may be errors

in estimating the AT need due to lack of data or inadequate information systems in institutions or, more generally, in countries. Therefore, giving due importance to data entries is important in determining the need for AT. Countries face challenges in accurately predicting and meeting the AT needs of the population due to limited information systems. The lack of structured and harmonized data leads to incorrect assessments of AT supply and demands. Therefore, developing strategic action plans to accurately understand and improve a country's population's AT needs is critically important (Al-Tayar et al., 2019, 5-6).

Individuals with disabilities may lack awareness of what assistive technological products and services are or about accessing these services. Health centers, government institutions or non-governmental organizations to which disabled people are affiliated may lack the knowledge, skills and awareness to direct disabled people to appropriate service providers. According to WIPO (2021, p. 219) the number of personnel specifically trained in providing access to AT is low in many countries. Because there are many types of disabilities, users need to know which type of assistive product will help them the most and where they can access these products. It is necessary to provide ways to access this information in health centers and in environments accessible to everyone.

Some ATs have very complex features and can provide services in different languages. The availability of language variability in service-providing products in accordance with the nationality of the disabled individual will ensure clarity. In addition, although the language efficiency of the region used is ensured, the technical equipment and use of the products may be difficult for some disabled individuals. Therefore, it may be necessary to provide training to people who are competent in this field.

Today, technology is constantly developing and progressing. For example, one technology can change very quickly, while another technology can change completely differently than before. For example, ATs, especially those with high technology, that have old software may need new updates. Or old devices may not adapt to new environments. Therefore, both manufacturers and disabled individual users may need to constantly update the systems.

While some AT devices may be complex for the elderly, some may not adapt to the situations of disabled people. For this purpose, those who design AT products need to determine very well the target audience that will use the products. The "knowledge gap" between the design team and target users can cause design problems and lead to ATs not being used or developed adequately. In order to solve the problem of information gap, those who design or produce the product may need to exchange information with disabled people.

Abandonment of ATs by end users still continues to be a problem. Among the reasons why end users stop using these technological devices is their inability to meet AT designs and needs (Federici & Borsci, 2016, p. 22-23). This situation causes the benefits obtained from AT procurement to decrease (Tao et al., 2020, p. 1028). In order to cope with this challenge, end users should be informed in detail by authorized persons before purchasing AT products, and if necessary, they may even be given the right to use them for a certain period of time. The practical usefulness, ease of maintenance and environmental compatibility of the AT to be recommended to disabled individuals are important details for its adoption by the individual. Those who will use AT should first adopt the products or services, so that they reduce the possibility of abandoning these products in a short time.

According to WHO (2022, p. 53), in order to combat these existing challenges and ensure the development of AT and make it stronger, it is necessary to address policy,

product, provision and personnel components. **Policies** funding, and programs to ensure universal access to ATs vary from country to country and require effective leadership and governance. ATs can be integrated into countries' health and social systems. An adequate and continuous source of funding can protect users from financial difficulties. This is only possible with the joint action of government institutions and insurance programs. **Products;** increasing the quantity, quality and diversity of products and making their prices affordable are important for AT. At this point, it may be necessary to develop various strategies. In order to reduce the cost of products, local manufacturing or imports can also be a solution. Investing in field at national and global levels, increasing the lifespan of products through repair and replacement, and creating efficient supply chains are among the improvements that can be made on products. **Provision;** it includes services including accessible information, user training and monitoring. Purchasing mechanisms can be used to increase the variety, quantity and quality of ancillary products and reduce costs; and information systems and the data generated can be used to help improve service delivery. **Personnel** who will provide the products (such as nurses, pharmacists, healthcare workers) can be developed to enable the development of assistive products. And it is important that these people are made aware or trained about ATs and that they are able to convey this information to the end user.

Conclusion

In this study, examples of emerging AT for individuals with disabilities are provided, aiming to raise awareness about the advanced state of technological developments in this field. Just as there is diversity in disabilities, there is also considerable diversity in AT. In this study, only a part of it could be addressed. While ATs struggle to keep up with advancing technology, the study addresses challenges despite the high impact that advanced technological products and services can have on improving the lives of individuals with disabilities and also according to challenges encountered suggestions are presented to overcome these challenges.

Information technologies and the internet enable people today to find easier, faster, and more economical solutions to their information and communication needs. As a result, individuals with disabilities can participate in socio-cultural, educational, and economic life. AT are used to enhance or increase the independence of individuals with disabilities, facilitate their participation in the social environment, and indirectly increase employment and well-being. In addition to traditional AT, the development of advanced AT has increased with the rise of digitization. Particularly, the development of high-level AT, such as the IoT, sensor technology, AI, robotics, and virtual/augmented/mixed reality technologies, as well as mobile applications, can be observed in the design of assistive products and services for individuals with disabilities.

Sources indicate that the majority of people with disabilities encounter discrimination and face a series of obstacles that prevent them from exercising their rights. Although access to assistive devices and technology is considered the foundation of fundamental human rights such as respect, autonomy, equality, and participation (Kritikos, 2018, p. 4), individuals with disabilities may still face various challenges related to AT. Among the challenges of AT are difficulties in accessing products and services, lack of awareness, high costs, lack of education in usage, and deficiencies in the public regulations and procedures related to individuals with disabilities in countries. Considering the anticipated increase in the elderly population and according to WHO predictions, necessary regulations regarding AT challenges should be made by governments, product suppliers, and service providers. Challenges related to AT should be considered as part of sustainable development and prioritized by governments. AT undoubtedly revolutionize the lives of individuals with disabilities. However, it should be remembered that technology alone has limited efficacy for the continuity of life. To fully enrich the lives

of individuals with disabilities, social and legal barriers must be eliminated, emphasizing that the "human" factor is as important as technology in this process.

The rapid advancement of information technology and the easy adaptation of the products and services we use are crucial in facilitating the use of AT for individuals with disabilities, enhancing their comfort in life, and promoting their social integration. In this sense, AT can reduce this inequality by enabling individuals with disabilities to be productive and participate in all aspects of life. AT can have a significant impact on empowering young people, allowing them to participate effectively in education and employment. Therefore, governments should prioritize them as a fundamental component of inclusive sustainable development.

The infrastructure necessary for delivering efficient AT services is an intricate concept that mirrors the intricacy of individuals' lives and requirements. It is imperative to tackle this comprehensively, acknowledging that AT serves as a fundamental avenue for accessing human rights, continually adapting to meet evolving needs.

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