Cutting Edge Assistive Technology Report

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mada
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مركز التكنولوجيا المُساعِدة

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Background

Cutting-Edge Assistive Technology Report intends to gather knowledge about the latest technological advancement and improvement that would potentially impact the development of Assistive Technology (AT) and Accessibility for people with disabilities in the future. This report is motivated by the need to be at the forefront of the AT industry and be able to adequately provide AT Services based on an understanding of upcoming technologies that would impact the AT industry and lives of PWDs. This study compliments also the ongoing innovation activities of Mada Assistive Technology Center in Qatar by setting the standards and requirements of the future Assistive Technology special needs within the region and worldwide.

Introduction

Assistive technology (AT) and its fast development are changing how services are delivered. The continuing proliferation and growth of more sophisticated everyday technology, especially information and communication-based devices and internet, brings the need to widen the range of such devices used. Within this issue, this report highlights the diverse nature and range of cutting-edge technologies that can be explored for new applications or solutions for people with disabilities, whether designed originally for such use or not. The contributions published here start from exploration of more initiative assistive technologies ideas and prototypes, moving to the existing tools and devices of information communications technology-enabled or computer-based devices and finishing with a study on some perspectives and ways.

Assistive Technology, which concerns the practical tools that can support functional needs of people who experience difficulties linked to disability or aging, allows them to live in the comfort of their homes and offices and schools. It is challenging to have remote care in smart homes with ambient intelligence, using devices, networks, and activity and plan recognition. Thanks to the fast growth of technology, AT related devices, tools and programs help overcome such challenges. The future is now dedicated to mobile applications and virtual reality and the potential influence of machine learning in robotics and artificial intelligence.

Nowadays, virtual and augmented reality and wearables technologies will not be limited to entertainments but it can be a way to help people with disabilities to explore the world that might be difficult or impossible in real life. Following to this emersion, the scope of this report is to provide an insight on potential technologies that are still in its infancy.

Cutting Edge Technology Areas

The rapidly evolving world of information, communication, and interactive technologies is growing exponentially. Each day new devices and programs are being developed to help people with disabilities overcome many of their challenges. Assistive Technology tools contribute to the academic and professional improvements for people and students with disabilities, specifically learning disabilities and emotional/behavioral disorders. The effects of particular technologies, especially for students with learning disabilities and emotional/behavioral disorders have been observed to be positive based on the needs of the individuals.

This report will focus on areas of technology that has experienced rapid proliferation in recent times both in terms of technological advancements and expansion of applications for use. These areas of technology are perceived to have major impact in improving the lives of PWDs in distant future, in ways that are yet to be explored. The following areas of technologies will be covered by this report:

- Virtual Reality
- Augmented Reality
- Tactile Screens
- Wearables
- Smart Solutions
- Mobile Applications
- Robotics

A number of significant initiatives related to the above areas of technology are currently being pursued with the goal of improving the lives of PWDs. These technology areas have initially emerged as futuristic facets of modern society (e.g. entertainment, healthcare, communication, etc.). Further research, development, and advancements in these fields have currently helped us to gain understanding of the full potential of such technologies in various aspects of life including assistive technologies.

Virtual Reality

Since its introduction, Virtual Reality (VR) technologies have been widely used in enhancing gaming experiences throughout the past few years. Over time, the realm of this technology has been implemented in various field of applications. As of the beginning of 2017, the total number of VR technology users is expected to exceed 43 million. The projected market value of this industry is estimated to reach $30bn by 2020. It is anticipated that the realm of VR hardware and software development will expand into further platforms like wearable and smart home devices. The development of wide-ranging VR applications has expanded to include technologies to benefit individuals with autism and other types of disabilities.

For instance, there has been much potential and discussion about the application of VR technologies using Head-Mounted Displays (HMDs) for people with disabilities. However, very few, if any studies, have yet to explore and investigate the acceptance, presence and ecological validity of these technologies. On the other hand, literature is well developed in areas such as virtual environments, virtual worlds and virtual reality, but few have considered the resurgence in head-mounted displays for PWD.

Current VR devices tend to be bulky, and are designed to work in specific environments that are custom built for it. This hinders the usability of such devices in daily applications. The continuous miniaturization of newer microprocessors and VR related innovation is expected to evolve these devices to be more user friendly and widely adaptable within various aspects of life. VR technologies are rapidly improving to have advanced graphics, motion sensing features, and sensory stimulation capabilities, to help deliver experiences that are realistic, attractive and appealing. At present VR solutions comprise of multiple devices like HMD and handheld controls (e.g. switches, joysticks, etc.). Such properties of VR solutions inhibits its portability and limit the scope applications they can be utilized for.

Virtual Reality and Disability

An area of disability where there has been a major interest in focusing towards VR solution is for challenges faced by individuals with autism. People within the autistic spectrum can experience difficulties in social interaction, and communication, emotional recognition, understanding the perspective of others and the ability to solve problems. Such difficulties can result to challenges in regulating emotions and thoughts which can ultimately lead towards social isolation and low self-esteem.

Virtual reality solutions can be used to improve individuals with autism who experience social attention and interaction problems by simulating an environment with virtual avatars of various characters and managing their behavior within the environment. In September 2016, research from the Center for BrainHealth at The University of Texas at Dallas demonstrated that virtual reality training programs for people with autism can produce positive results. It was observed that virtual reality training platforms can help individuals with autism to overcome the anxieties in social situations by allowing them to familiarize themselves with different social scenarios (classroom, etc.) and participate freely without fearing for the consequences of being judged.

Virtual reality systems being explored includes features like helping to train wheelchair users to navigate a virtual world, for example a busy street or shopping centre. Such systems allow the user to improve skills for moving around and avoiding obstacles in a virtual setting before putting these into practice in the real world. The systems being explored currently involve combination of input devices like HMDs, joysticks and trackballs.

VR technologies can be utilized to support PWDs to lead an independent life wherever possible and to interact with others. VR can teach them basic skills which able bodied people often take for granted but nevertheless, are still important for day to day living. These include cooking, shopping and other household tasks. The aim is to boost confidence and self-esteem thereby leading to improved quality of life. The disabled person is able to engage with society and feel a sense of value from doing so.

Access to nearly infinite fictional, virtual worlds opens up space for simulating interactive and therapeutic environments that would otherwise be difficult or impossible. As the technology continues to improve and prices get lower, we'll see a growing use of VR systems to help people with a broad range of conditions. It expands to numerous ways such as VR systems with voice activated software, virtual worlds and fully immersive systems where the person is able to navigate a virtual world. This would likely be a part of a broader move by society as a whole to embrace these futuristic advancements. The virtual reality technology is a promising tool that provides a safe, inviting and effective platform for improving social skills, cognition, and functioning.

Augmented Reality

Augmented Reality is an extension of computer vision, which is the ability of computers to make sense out of images. AR is typically thought of as computer-generated assets placed over the real world using some type of display, including wearables. However, augmented reality actually includes whatever useful visual perception a person might have, supplemented with additional computer-generated sensory information to help us better understand our world.

One of the common feature capabilities considered within AR related assistive technology is navigation. Some promising techniques of using AR technology for navigation can include:

- Capability to track physical position and coordinates
- Object and face recognition algorithms
- Utilization of stereo cameras and infrared beams for depth calculations
- Optical flow calculations, including time to collision, motion detection, focus of expansion, and inertial information
- Identification of contextual properties (sense of place from either the user, a previous user, or a knowledge map)

Augmented Reality and Visual Impairment

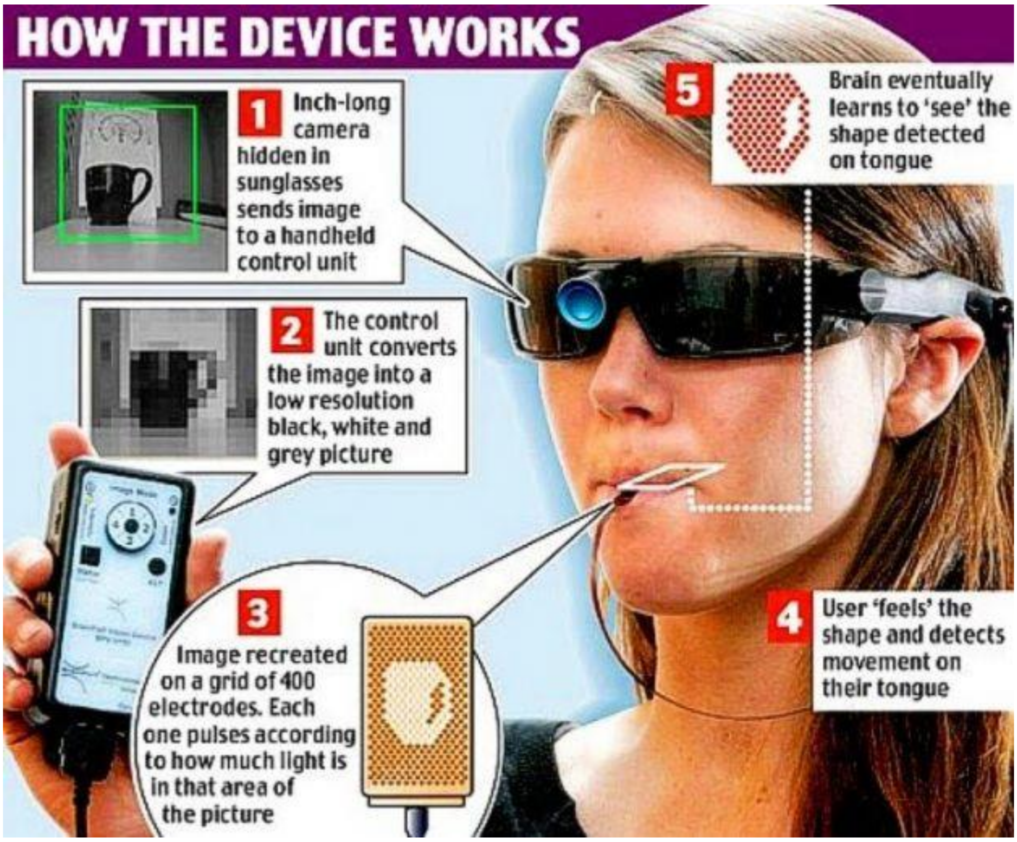
Augmented reality can provide assistance for each level of visual impairment, inclusive of people with low vision or no vision. People who have low vision can use an app or product, such as Pebble HD, and the SmartLux Digital to help them decipher an image or text. These technologies allow users to view objects in variable brightness, high-contrast tones and zoom levels in High Definition Quality.

AR technologies also allow the feeding of additional information sources to a person while they navigate the world. Such technologies include but are not limited to augmented reality glasses, object recognition technologies, and automatic mapping engines. These technologies can be combined to produce new apps for helping persons with a visual impairment navigate better in their environment, both indoors and outdoors.

Another approach to augmenting information for people with visual impairments is "sensory substitution" or "sensory addition." In these cases, alternative sensory channels are used to feed information to a person with a disability as a way of augmenting their normal everyday experiences.

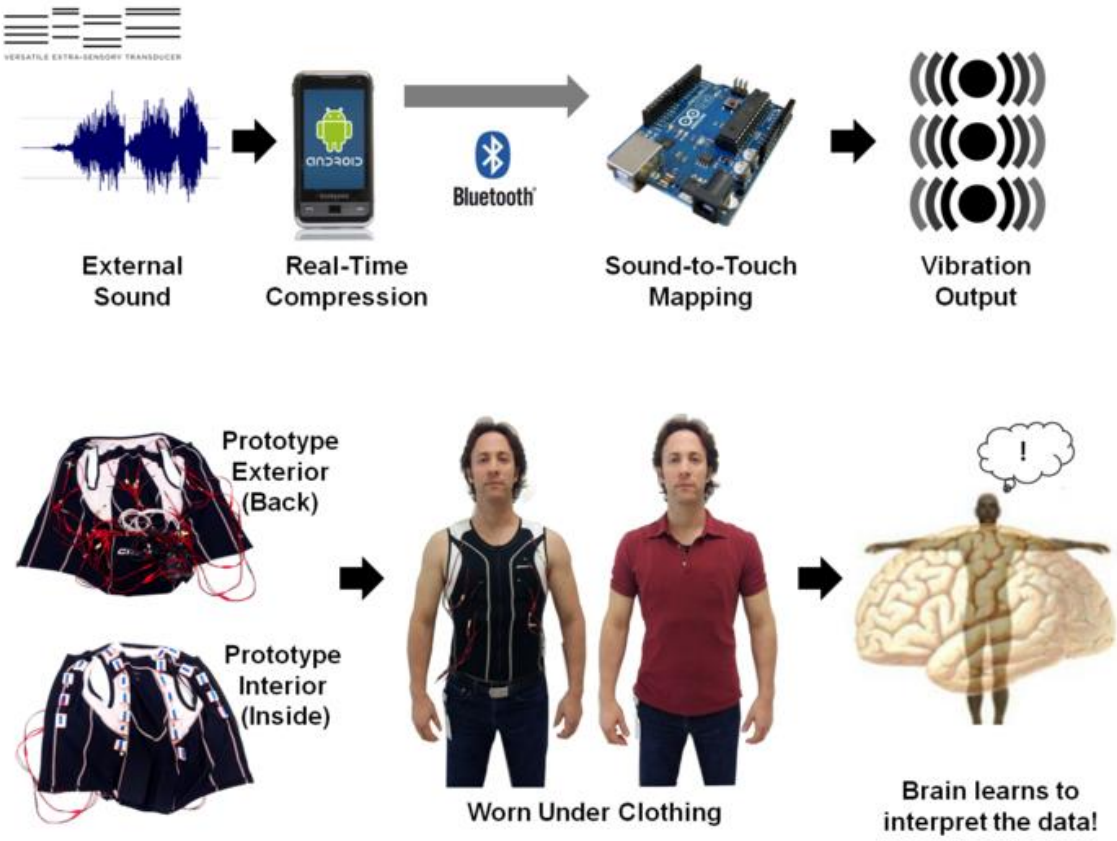
Examples of projects using alternative sensory channels include:

- BrainPort (uses tongue to "see") - is an oral electronic vision aid that provides electro-tactile stimulation to aid profoundly blind users in orientation, mobility, and object recognition as an adjunctive device to other assistive methods such as the white cane or a guide dog. The device translates digital information from a wearable video camera into gentle electrical stimulation patterns on the surface of the tongue. Users feel moving bubble-like patterns on their tongue which they learn to interpret as the shape, size, location and motion of objects in their environment



- **Orcam (Use of bone conduction to "see")** - is a small device that attaches to any pair of eyeglasses and acts like a personal sight companion. The device will provide audio feedback through bone conduction regarding what the user is looking at, reading and who he/she is seeing. The device can be controlled using hand gestures, like pointing, and waving. Orcam is ideal for individuals who have limited sight, are completely blind and may even help those with dyslexia or dementia. It comes with a wide knowledge of common products and things, and the wearer can easily and quickly teach it new things and especially people's faces so it can recognize friends, family members, and other preferred acquaintances.

- **Versatile Extra-Sensory Transducer V.E.S.T. (Use of skin on the back to "see")** - is an actual vest that a deaf person will wear under their shirt. The smart phone of the user will capture the sounds around them and send them to vibration motors on the vest real time, which will be converted to touch in the form of vibrations. These vibrations, or electric signals, are then sent to the brain directly where they are interpreted into information. With this vest, deaf people will be able to do several things that are typically either not possible for them or very difficult, like listening to traffic sounds in their surroundings, music, etc.



A report on the growing market for assistive technologies suggests augmented reality could play a key role. "Steady advances in materials and technologies associated with communications, electronics, materials, smart materials, mobile location, and sensors will stimulate robust market growth," according to BCC Research.

The advantage AR technologies is that they can often be used in complement with other existing technologies like smartphones with cameras, and other relevant sensors. Such properties allow AR features to be easily incorporated into well explored solutions resulting to an innovative outcome which can often be cost-effective. The future of AR will rapidly expand with various simple and complex solutions to serve the needs of PWDs. However, complex solutions like BrainPort will require a high degree of training and subject to abstract user-perception of the environment making them suitable for specific users only.

Touch Screens and Accessibility

A touch screen is a computer display screen that is sensitive to human touch, allowing a user to interact with the computer by touching pictures or words on the screen. Touch screens today are frequently used for information kiosks, automated teller machines (ATMs), airline e-ticket terminals, and customer self-service stations in retail stores, libraries, and fast food restaurants. Touch screens are also the most common means of input for personal computers and smartphones.

Since touch screens were designed to provide user-friendly, intuitive computer access without requiring a keyboard and mouse, it logically follows that touch screens can be excellent tools for people who experience difficulty using keyboards and mice because of physical or cognitive disabilities. Touch screens are being used as assistive technology for many years, providing an alternative to standard input devices for users who need access to standard applications. Specially designed applications are often developed specifically for touch screen use. These applications typically include large icons and a simple intuitive design layout.

Despite advantages to some, however, touch screens can present barriers to others, such as people with physical disabilities who are unable to touch the device, as well as people with low vision and blindness, for whom the device provides no controls that can be appreciated by sense of touch.

For people who are physically unable to touch the device, an accessible product is one that allows the individual to enter commands by voice or by pressing the controls with a mouthstick, headstick, or other similar device (stylus). Some touch screens support stylus input, and others do not. The difference is in the device's touch sensor technology, of which there are several common types:

- Resistive touch screens are pressure sensitive, so they can be operated with any input device, including a gloved hand or stylus. However, resistive screens can be easily damaged by sharp objects, and they offer only 75% clarity, which may create additional problems for people with low vision.

- Capacitive touch screens offer higher clarity and are more durable, but they do not respond to gloved hands or most styluses (the pointing device must be grounded).

- Infrared touch screens can be operated by either human touch or stylus. They also provide high clarity and durability. They are more receptive, however, to false responses (by dirt, flying insects, etc.) and do not respond well to users whose fingers hover before pressing a control.

- Surface acoustic wave (SAW) is a more advanced technology that provides high clarity and durability and can be operated by either human touch or stylus. This technology, however, is considerably more expensive than the more common technologies and is not as well supported.

People who are blind and some people with low vision are unable to locate the controls of a touch screen device. These individuals may be able to locate and activate controls if they are labeled in a large high-contrast font and/or if audible output is provided to help identify the controls. Audible output is also required for users with visual impairments to access the information that results from activating the controls.

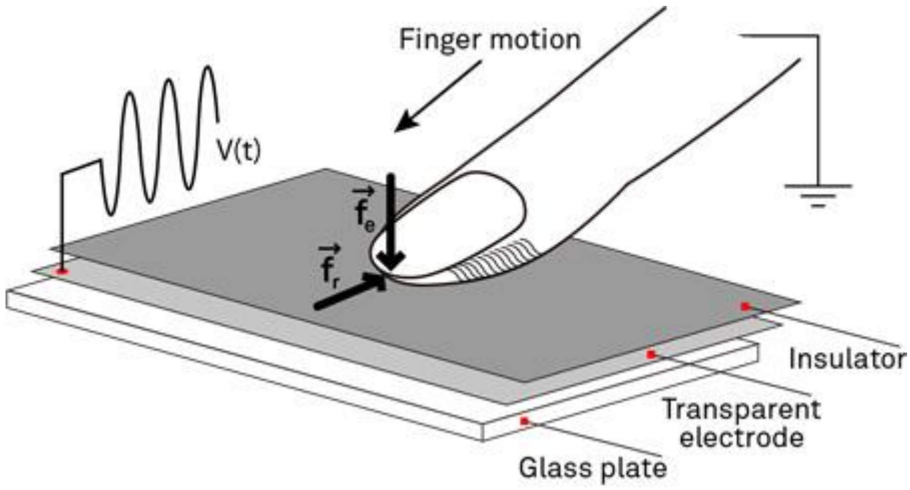
Tactile Screens

Touch screens are ubiquitous today. But a common complaint is that the smooth surface just doesn't feel as good to use as a physical keypad. While some touch-screen devices use mechanical vibrations to enhance users' experiences of virtual keypads, the approach isn't widely used, mainly because mechanical vibrations are difficult to implement well, and they often make the entire device buzz in your hand, instead of just a particular spot on the screen.

An interesting field in computing is haptics, which is the science of applying tactile sensation to human interaction with computers. This has the promise of providing a method for accessing touch screen information in an alternative format, such as through audio or tactile sensation.

Lund University in Sweden published a paper entitled User-Centered Design of Non-Visual Audio-Haptics in 2008.

A group of researchers composed of members from Disney Research in Pittsburgh, Carnegie Mellon University, and the University of Paris Sud, are currently working on a type of tactile feedback that has potential for use within the AT industry. This feedback mechanism is called electrovibration, the technique uses electrical charges to simulate the feeling of localized vibration and friction, providing touch-screen textures that are impossible to simulate using mechanical actuators. This technology being developed is called TeslaTouch.



The touch panel is made of transparent electrodes on a glass plate coated with an insulating layer. By applying a periodic voltage to the electrodes via connections used for sensing a finger's position on the screen, the researchers were able to effectively induce a charge in a finger dragged along the surface. By changing the amplitude and frequency of the applied voltage, the surface can be made to feel as though it is bumpy, rough, sticky, or vibrating. The major difference is the specially designed control circuit that produces the sensations.

A California based company, Tactus Technology is working on technology that can generate physical keys from a flat surface on demand, giving a smooth, unbroken surface for general touch-based interaction, and a physical keyboard when needed. The company's innovation uses a microfluidic panel, routing liquid through invisible channels to expand specific areas of the outermost layer of a touch panel, producing protrusions and bumps where previously there were none.

Tactus launched its first product called Phorm which is an iPad mini case that incorporates the tactile technology into a thin front panel, similar both in size and in method of application to a standard screen protector. It's paper-thin, and it offers virtually no change in the optics of the display when looked at. The Phorm itself also doesn't add that much additional size to the iPad mini's sleek frame, adding about as much bulk as one might expect from a fairly durable protective case.

The Phorm case itself holds the fluids needed for the transformation it enables, as well as the circuitry required for triggering the key generation. There's a single large switch on the back that lets the user turn the tactile keys on and off. The primary feature it offers is the ability for keyboard keys (on the touchscreen) that rise up and down. They are touch-capable ridges that suggest the location of the device's keyboard (in portrait orientation) and have a little bit of

give on finger press. But they provide a lot more presence than a flat display for typing by touch alone, and they disappear completely when not in use.

Tactus is currently working on designs for the newer version of iPhones and iPads, and they've even produced a prototype using a generic Android tablet reference design that incorporates their tactile keys right into the display of the device, without requiring any additional parts or user installation. This is a technology that is still in its relative infancy, but is seeing its start to make way out to the consumers.

Wearables

Wearables are devices which are usually worn on or near the body and since they do not need to be actively held or carried (like a smartphone), they leave both hands free. Operating the system sometimes requires touch, but often movement, gestures, and voice commands can be applied as well. Output can be visual on a screen, but also through a combination of sound, spoken words, vibration, movement, temperature change, small shocks, etc. Wearable technology increasingly mediates information-sharing and communication. Public and commercial agents offer services using these devices that range from health-related monitoring and advice to online shopping, wayfinding, navigation, and communication services. Wearable technology potentially gives people with visual and other sensory disabilities better, less conspicuous, and easier access to information and services. The advantage of wearable technology is that they enable users to collect, process, and transfer data even without physical interactions with the device.

Wearables Capabilities to Improve Quality of Life

Before the emergence of wearable technology, routine solutions for vision loss, hearing loss, or other disabilities could be cumbersome, very expensive, or exhausting to maintain. Twenty years ago, glasses were as thick as your vision was bad and people could not wear contacts with an astigmatism. At the same time, hearing aids were visually obtrusive and only offered limited settings for different listening environments. As technology has progressed, so too has the functional capacity of wearable devices. Now, wearables offer more options to more people than ever before – especially to people with needs outside the average consumer.

Today, the power of wearable technology is remarkable. Wearables today can be associated with gadgets like bracelets, smartwatches, earphones, and other innumerable on-person devices that have been launched in the last few years that are designed to directly enhance the quality of lives of PWDs. There are wearables that can track blood sugar levels, alert users with diabetes when they need their insulin, to asthmatic episode frequency and severity, allowing asthma patients to communicate a spike in attacks with their doctors in real time. Additionally, wearables like fall detection devices can also identify emergency situations when the user loses balance and collapses during when the device automatically alerts emergency services and/or immediate family members of the user.

Wearables can genuinely contribute to increasing the prevalence of healthy lifestyle choices, yet wearable technologies are capable of much more than tracking and relaying user information. They can improve overall quality of life for people living with disabilities by delivering increased access to communication and enhanced environmental awareness. These benefits of wearable technology provides an increased sense of independence for the disabled community.

Wearables as Assistive Technology

Recently, Novartis launched an app for the Apple Watch that helps blind people travel to a particular destination by vibrating to communicate turn-by-turn directions. GN ReSound, introduced an iPhone compatible hearing aid that enables people living with hearing loss to adjust their settings of the hearing aid directly from their iPhone, rather than having to manually adjust it from the device. The smart phone app delivers control over settings like wind-and-noise-reduction, allowing wearers move from one sound environment to the next with ease. Innovations like these that combine PWD needs with technological developments are a revolution for people with disabilities because they integrate seamlessly in their everyday lives and thus allowing them to perform tasks that they could not carry out otherwise.

Wearable technologies promise simplicity and ease from helping monitor symptoms in real-time to helping a blind person navigate new neighborhoods. Even more, for people with disabilities, personalized wearable technology allows for unprecedented environmental control – giving greater freedom and independence than ever before.

Nowadays, a number of innovative wearable devices and solutions for people with disabilities toward improving communications and access to information are being designed. Following are the examples of some such wearables:

Myo armband - is a wearable gesture control and motion control device that lets the user take control of their phone, computer, and other compatible devices through a touch-free interface. It can be worn on the forearm allowing a series of motion and muscle sensors to be able to track movement and muscular impulses. Researchers at Arizona State University have found a way to use the Myo controller to translate sign language. The system, which is known as Sceptre, uses a pair of the wearables that can match gestures and signs to a database and then display it as a text on a screen. The team has managed to successfully recognize a series of words and phrases including 'headache', 'upset stomach' and 'all morning'.

Dot Braille Smartwatch - is the world's first Braille smartwatch. Dot helps people with blindness access messages, tweets, read books, etc.. Unlike most assistive smartwatches for the blind, which rely on audio prompts, the Dot projects messages through braille characters on a screen. It can connect via Bluetooth to any smartphone then retrieve and translate the text from an email or messaging app into Braille for its user. Information is displayed by two sets of six dots, which raise to produce four braille characters at a time. New characters cycle at speeds ranging from 1-100 per second, with users also able to send simple replies or actions back through the device's two side buttons.

Leap Motion - is a small USB peripheral device which is designed to be placed on a physical desktop, facing upward. It can also be mounted onto a virtual reality headset. Using two monochromatic IR (infrared) cameras and three IR LEDs, the device observes a roughly hemispherical area, to a distance of about 1 meter. Leap Motion could recognize hand gestures and translate them into interface commands. The device can track finger movement to 1/100th of a millimeter and is 200 times more sensitive than other motion control devices currently in the market. This tool can be a good start for sign language recognition tool or a translation tool from any sign language to text.

Wearable technology as assistive technology, can be classified using various parameters. We categorize the different wearable devices based on the major scope of the device application:

- Navigation assistance for visual impairments
- Assistance for hearing impairments
- Assistance for controlling electronic devices

Wearables are increasingly being in used for AT applications to meet various needs of the PWDs. There are a number of reasons how people with disabilities can benefit from using a wearable technology for example an assistive eye-glass (e.g. google glass) can be used for the following applications:

- By using the built-in camera, GPS, sensors and audio output, those who are blind or visually impaired can navigate or experience their environment.
- The camera and audio output can help those who are dyslexic to read. For example, the eye display can pull up image searches for words captured with the camera
- Those who have difficulty communicating can use the built-in voice controls, eye display and audio output to express themselves. Vibrations could be used to communicate emotions or gestures.
- People who are blind or visually impaired can tour museums or any monument.

As the field of wearable technologies continues to expand, so too does the opportunity to help people with disabilities access the world and live effortlessly.

Smart Solutions

One clear means of keeping a handle on the expanding requirement for independent living residences and avoiding a care crisis in the process lies in the connected smart solutions. Smart Solutions are becoming a viable option for people with disabilities who would prefer to stay in the comfort of their homes rather than move to a healthcare facility. This field uses much of the same technology and equipment as home automation for security, entertainment, and energy conservation but tailors it towards people with disabilities. A decade ago, a smart home seemed like a luxury item and out of reach for many, but nowadays these assistive technologies are more easily accessible for those who want it, but more importantly for those who need it. Loss of vision, hearing or mobility affects the way these people function in their daily lives. No one, including those with limitations, wants to have to rely on constant assistance of others to meet their daily needs or conduct their daily chores.

Smart homes, through the use of assistive technology, compassionately allows for the disabled and elderly to maintain control over their environment and daily activities and offer a more positive quality of life by allowing them to maintain their dignity. These smart homes and assistive technology possibilities empower the lives of the disabilities. With all of the physical and emotional stress they have had to endure, smart home helps give them strength and hope for the future.

Smart homes are no longer design concepts of the future. They are being built now, and are making direct impact on the lifestyles of the people. The aim of smart home systems is to create an environment that is aware of the activities taking place within it by integrating a combination of smart solutions. For the PWDs, smart solutions give them opportunity for independence, which will help them gain confidence and determination. Many of the technologies currently used in smart homes can be adapted to meet a number of needs, while connected technology solutions that are designed with particular circumstances such as blindness, deafness or immobility in mind are beginning to emerge. Putting such systems into people’s homes can reduce or even eliminate the need for dedicated care, and grant independence to those who might otherwise struggle with day-to-day activities.

Novelty vs Necessity

For so many years, having a smart solutions has been considered as a novelty. The convenience offered by such technologies in combination with unconventional and avant-garde features make them appealing and easily marketable as a novelty. For the PWDs, smart solutions are no longer considered as a novelty but rather a necessity. These solutions allow PWDs to maintain or increase their functional capabilities and provide them with independence.

Smart solutions allow homes to become intelligent using inbuilt technology that are controlled by a computer network. A smart home environment is usually equipped with a collection of inter-related software and hardware components to monitor the living space by capturing the behaviors of the resident and understanding their activities. By doing so, the system can inform about risky situations and take actions on behalf of the resident to their needs. Remote controls are now being replaced by intelligent devices that automatically fulfill its task based on its analysis of user behavior. All of this is made possible by the miniaturization of electronic devices, accompanied by a huge increase in the availability of internet connectivity. The potential applications of such smart solutions are virtually limitless, and they have the ability to greatly improve quality of life. This is enabled by the miniaturization of devices, the emergence of the internet as a favored communications method and the proliferation of powerful and smart mobile devices.

Smart Automation Functionality

Many new systems are comfort and safety oriented. These applications enable a user to change his or her thermostat remotely, dim or increase the intensity of lights, control door locks, activate alarm systems, etc. While these applications certainly add convenience for all users, the applications take on a whole new level of importance when used by persons with disabilities.

The technology in a smart house can start at the front door. Such technologies can allow functions like enabling a PWD to attend the front door. Closed-circuit TV can show who is at the door and an intercom used to ask what the person wants. This set-up is ideal for someone who is immobile or who could take a long time to get to the door. If they decide to let a visitor in, a person confined to a bed could touch an icon on their phone that automatically opens the door.

A smart house can also have a Leave Home function, which is accessed on their smart phone. With a touch of the phone icon a person can close all doors and blinds, turn off all lights and heating or cooling, lock the front door on exit, and turn on the security system. Sensors that detect movement can be installed throughout a house and automatically turn on lighting and heating when a room is entered. There is also carpet underlay that is full of sensors and detects movement. The underlay can tell if a person is standing or lying on the floor, so it can detect when a person has fallen and needs assistance. The house's computer system can also be programmed to then alert family members or a 24-hour care center.

Sensor technologies can detect individuals moving in and out of bed at night and automatically turn on the lights. When a person enters the site, its lights will automatically come on. Data collected from sensors and appliances could enable the house to know the routine of a resident. All of these smart home features can be controlled by a tablet, computer or phone. From using a smartphone as a control system to replace any switches that are difficult to reach, to automatic doors and electric cabinet tracks.

The most obvious smart automation technology to mention is lighting control. The ability to control your lights via a smartphone app is an ideal tool for individuals who have mobility challenges or trouble reaching light switches. For people who use a wheelchair, as well as others who have mobility challenges, opening doors can be a hassle. Performing such daily tasks could be difficult and unnecessarily so given that an automatic opening system can easily be fitted to any door at home. In domestic settings an automatic door is slightly different from the type that we all come across in our daily lives at the entrances of public buildings, shops, offices and so on. Usually these commercial systems use a sensor to detect when a person is approaching the door, and then open the door for them. In home settings a different approach is required because one may want to go close to the door without actually going through and opening/closing it. A powered door opening system for the home should either be controlled by a wall mounted switch, or connected to a control system to allow you to open and close the door using a mobile app.

Opening the door to visitors can be difficult for several different groups of people. Those with hearing impairments may not be able to hear a doorbell, while those with mobility challenges may find it difficult or painful to get to the front door to open it. A networked door entry system and wireless lock combine to offer an excellent solution. A good quality home automation controller can be combined with a video intercom and wireless lock so that the user can receive a phone alert when somebody rings the doorbell, and then speak to them via the intercom and let them in with a simple tap of the screen. For people with hearing impairments this means that they can get a tactile vibration alert from their phone when somebody comes to the door, and for those with mobility issues it also means that you can open the door without having to move anywhere.

Coupled with accessible smartphone interfaces, smart solution technologies hold enormous promise for persons with disabilities, improving quality of life by facilitating independence and self-empowerment. In today's time any electronic systems at home with sensors, IR, Bluetooth or Wi-Fi connections can be easily interconnected to one centralized unit for easy access and control by giving it the full meaning to the term 'Smart Solutions'.

Smart Home Capabilities

A smart home involves the interconnection of appliances and other features by sensors, actuators and computational units, and the use of information and computing technology to anticipate and respond to the occupant's needs; or systems equipped with sensors and actuators, which communicate with each other, monitor the occupants and support them in their daily activities. This integration of home systems, including with the assistance of multivalent systems, allows communication between them through the home computer and the simultaneous control of different systems in operating or pre-programmed modes using speech and single buttons.

The application of data mining and machine learning techniques to this data can be used to discover frequent activity patterns and predict events in order to automate interactions with the environment and respond in a context-aware manner. Context awareness can also be used to facilitate adaptation to changing requirements. The smart and context-aware functions can be supported by active or passive radio frequency identification device (RFID) tags which are able to identify people, animals and objects, and which are now inexpensive. The tags comprise semi-conductor chips and an antenna which transmits data to a wireless receiver. Mobile robots with RFID readers can be used to navigate tagged environments and locate and move objects. Advances in technology mean that sensors can now be located in the environment rather than on the robot, reducing its size and weight.

Unfortunately, though various solutions have been proposed, RFID tags are an insecure technology and could be used to track people and their activities. The collection of user and house data also raises privacy management and data security issues, with the possibility of unauthorized and even fraudulent uses of the data, including in ways that may threaten the security of the user and/or their property. There are therefore trade-offs between the benefits and the potential loss of privacy. It should be noted that technological support for independent living and working can be provided without the use of smart technology and could include robot manipulators.

However, it is only relatively recently that work on smart houses has considered the incorporation of robots in the design, though smart houses themselves can be considered robots. Non-smart systems would have the advantages of reduced cost and be less intrusive than smart ones, since they would not involve extensive monitoring. They have the disadvantages of reduced functionality and probably also reduced robustness, as it may be easier to build failsafe's and redundancy into smart systems, thereby reducing the risks of malfunction. Initial approaches to smart home design involved a centralized architecture with all appliances connected to the home network and controlled by the home gateway. However, the availability of ubiquitous computing devices has facilitated the use of distributed architectures.

Smart homes should comply with open standards to avoid incompatibility between different products. Examples include the Open Services Gateway Initiative (OSGi), which is an open standard service-oriented component model for deploying services in smart homes. Its use in smart homes is generally based on the client-server model, but it risks single point of failure in the home gateway. A study of different projects has indicated a greater focus on physical and functional health rather than social interaction, possibly because it is more difficult to integrate social interaction technologies.

A range of technologies intended to improve quality of life can be incorporated into smart homes. These technologies include but are not limited to: (i) an induction loop amplifier for hearing impaired people; (ii) a video entry phone system and keyless door lock; (iii) powered door and window opening and closing systems; (iv) infrared shower tap and tap and toilet flush controls; and (v) a pull cord and portable alarm system. Preprogrammed devices include heating controls and audible reminders via the telephone system.

Smart home devices can also include:

- Pressure pads to identify movements and trigger other appliances, such as lighting
- Window sensors which close the windows when the house is empty
- Smoke detectors which interact with door and window opening devices
- Curtains which automatically open and close at daylight and night fall
- Touch-screen interfaces between users and the operating system.

Usually, a central control unit integrates all the components, and all systems are connected by a home network which includes both wired and wireless communication modules.

Key Systems for Smart Solutions

ZigBee Alliance

ZigBee, is a global standard of communication protocol formulated by the Institute of Electrical and Electronics Engineers (IEEE 802.15) working group. ZigBee is a technology protocol of data transfer in wireless network. It also can be described as a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless networks. ZigBee has a low energy consumption and it is designed for multichannel control systems, alarm system and lighting control.

ZigBee has focused its efforts on wireless sensors for smart products. Its standard is a semi open standard, with a license for manufacturers. The alliance comprises of over four hundred members, and currently has certified over 1,000 products. ZigBee Home Automation 1.2 and

ZigBee Light Link (adopted by major light bulb manufacturers) rely on low energy consumption and are among the popular solutions offered by the alliance members. Developing products using the ZigBee protocol ensures that multiple smart devices can work together cohesively within the same network avoiding inter-incompatibility between the devices.

AllSeen Alliance

AllSeen Alliance, has been formed around Qualcomm's AllJoyn open-source technology to connect devices. Products, applications and services created with the AllJoyn open source project can communicate over various transport layers, such as Wi-Fi, power line or Ethernet, regardless of manufacturer or operating system and without the need for Internet access. The software is openly available for developers to download, and runs on popular platforms such as Linux and Linux-based Android, iOS and Windows, including embedded variants. The system itself is an open source project which provides a universal software framework and core set of system services that enable interoperability among connected products and software applications across manufacturers to create dynamic proximal networks.

Insteon Smart Home

Insteon is a US based developer of home automation hardware and software. The technology allows light switches, lights, thermostats, motion sensors, and other electrical devices to interoperate through power lines, radio frequency (RF) communications, or both. There are over 200 products featuring this technology. Insteon technology uses a dual-mesh networking topology in which all devices are peers and each device independently transmits, receives, and repeats messages. Insteon markets two different central controllers: its own brand, called the Insteon Hub, and a newer HomeKit-enabled Insteon Hub Pro designed for Apple HomeKit compatibility.

The Road Ahead

As we have discussed above, the potential for the Smart Solutions to improve the quality of life of persons with disabilities is enormous. However, barriers still remain that will need to be addressed before this can become widely adopted and offer the benefits we have discussed.

- Accessibility: Perhaps the most significant barrier to persons with disabilities being able to take full advantage of integrated Smart Solutions is ensuring that all of the players in the ecosystem consider accessibility when developing new products and services. There are a wide variety of companies and organizations that contributes to the Smart Solutions market, including device manufacturers, handset manufacturers, networks and application developers. In order to create a Smart Systems that works for everyone, accessibility and interoperability must be a consideration at each stage of the development process. At a minimum, all parties involved in the development of Smart Systems devices and applications should commit to upholding the principles of Universal Design.

- **Broadband Access and Adoption:** Smart Systems must have multiple devices connected together that work cohesively in order to allow the overall Smart Solution to be effective and usable. While the adoption of wired and wireless broadband has exploded in recent years, there are still sectors of society that are not users of broadband (e.g. non-adopters PWDs, older adults, etc.). While the reasons for not having internet access can range from not understanding the value, to not being able to afford it, to not having access to the necessary infrastructure, the end result is the inability to use integrated Smart Solution Systems.

- **Standardization:** As is often the case with emerging technologies, the multiplicity of Smart Solution technologies that the industry is developing has raised questions about how all of these products are going to communicate. Several different bodies are already working on standards related to the Smart Solutions. One such body is the IEEE Standards Association (IEEESA), which has approved and published about 80 standards relating to IoT applications—including Bluetooth, ZigBee and Wi-Fi—and has at least 40 additional standards in development. The ZigBee Alliance has also developed its own standards. Others however, note that the large number of standards in the market today is not necessarily bad, nor unexpected. There are many questions and issues around standardization that have yet to be worked out. While common standards and interoperability will be crucial for allowing persons with disabilities to take full advantage of these technologies, we are optimistic that a more streamlined standardization landscape will emerge. The diversity of current standards may in the end be a positive approach, with greater interoperability as a result.

- Privacy: Smart Solution applications will, often by necessity, collect data about their users. For example, it could measure how a user moves around in his or her daily life, data that enables applications to understand living patterns and give connected devices the information required to predict the user's needs. Naturally, this degree of information collection raises questions about privacy. It will be important that users of Smart Solution applications including users with disabilities be educated about what data will be collected about them by a particular device or system, and be given the opportunity to exercise choices about that collection.

Integrated Smart Solution Systems are still in their infancy, and it will take years before it becomes a part of our daily lives. Significant challenges still remain before the Smart Technologies can fulfill its promise to revolutionize the lives of its users particularly users with disabilities. Many factors will have to evolve, including guidelines for standardization and interoperability of devices, the extension of broadband internet networks, protection of privacy, improved security of data and a commitment to accessibility by all parties in the Smart ecosystem.

Despite these challenges in front, it is important not to lose sight of the significant benefits the Smart Systems can bring. If industry stakeholders incorporate universal design and input from the disability community into their development, Smart Systems will mean more independent living, more personalized care, more flexibility and mobility and better employment and education outcomes through wearable and mobile technologies.

Smartphone and Tablet Applications

Smartphones and tablets have more than just one function, unlike other assistive technology devices. Smartphones, in particular, allow users to place and receive phone calls, text messages, play games, listen to music, participate on social media, and a myriad of other functions. By using a smart device capable of multiple functions, the idea of using many individual pieces of assistive technology begins to fade away.

Smartphones and tablet PCs have revolutionized mobile technology and the means of communicate today. This technology have also transformed the Assistive Technology (AT) market for people with disabilities. These mainstream devices provide people with mini-computers that are portable and they are much more affordable than many dedicated AT or AAC devices.

The introduction of apps (software applications that run on mobile devices and tablets) has revolutionized the use of smartphones. These 'apps' can be downloaded to smartphones or tablet PCs to provide a particular service or that allow to interact with a website or a web-based service. There are thousands of apps available for download with new ones constantly being developed, so there is a high probably that an app for completing any particular task already exists.

There are apps available that have been designed to meet the needs of people with disabilities, for example, Prologue2Go, a text-to-speech app for people who have difficulty with their speech. Being able to download apps to the smartphone or tablet PC means having a small, integrated device to store the required data, rather than having a number of pieces of stand-alone equipment. This makes it cheaper, easier and more efficient for people with disabilities to perform a wide range of tasks. It can also help to remove the stigma of having a large dedicated A.T. device that stands-out, as these days everyone walks around with a phone in their hand. For example, before the introduction of smartphones and apps, someone with a visual impairment may have needed to bring a number of items out and about to 'see' for them. They may have carried a money recognition device, a color recognition device, a screenreader and a magnifier. Now they can download a screen-reader app, magnifier app, money recognition app and color recognition app to their phone and just carry the software around.

As the app market is constantly growing and changing, it would be impossible to list all the relevant disability apps. Instead, the main types of apps available with examples are described in this section of the report. This will allow us to gain an insight on the potential of mobile applications within the realm of AT.

Smartphone & Tablet Integrated Accessibility Features

Smartphones and tablets can be considered as an AT by themselves. Different smartphones run on different operating systems. The operating system is the software the phone uses to provide all its functionality and it determines how the person navigates around their phone, accesses the internet, finds and downloads apps and their general experience of the phone. Some phones operating systems' are more accessible for people with disabilities than others, though most phones today have some basic accessibility functions that make them easier to use. The main operating systems for smartphones and tablets in the market are Apple iOS and Android, however other players like Blackberry OS and Windows also exist in the market.

Apple Operating System (iOS)

The Apple iOS (currently Version 10) is the Operating System used for Apple iPad tablets, iPhone smartphones and the iPod touch. This operating system has a number of integrated functions that allow or improve access for people with disabilities.

VoiceOver: is a built-in screenreader that allows to use the iPhone even if the user can't see the screen. He/she can touch the screen to hear a description of the item under his/her finger. For example, it will announce battery level, whose calling or which app the finger is on. Then double-tap can activate the desired app/feature. When typing a note, email, or text message, VoiceOver echoes each character on the keyboard as they are touched, and again to confirm when the character is entered. It can also speak each completed word if required. VoiceOver also includes a Braille keyboard, enabling direct braille entry.

Zoom: allows to magnify the entire screen of any application being used in order to help the user see what is on the display. Double-tap on the screen enables the Zoom feature, then one can adjust the magnification from 100% to 1,500%.

Siri: allows to perform tasks on iPhone hands-free using just the user's voice. It allows to send messages, schedule meetings, make phone calls, and more. This voice recognition functionality can be useful for people with a visual impairment or people with limited dexterity. Siri is also integrated with VoiceOver so the user can ask Siri a question and hear the answer read out loud.

Speak Screen: reads the contents of a page back to the user. For example, the user can use Speak Screen to read out emails, iMessages, webpages, and books. This may be helpful if the user has a hard time reading the text on the device.

Dictation: is a speech-to-text feature that allows the user to speak the desired text to be typed. To access Dictation, the user has to tap the microphone button on the keyboard, and dictate the desired text to be typed and the device converts the spoken words into text.

Face Time: provides video calling, which allows people to see the caller on their screen in real-time. This can be helpful for people using sign language or lip reading.

Font Adjustments: allows to convert the text to a larger size so it is easier to read. The user can also to bold text to make it heavier and easier to see.

Invert Colors and Grayscale: provides higher contrast or reduces color to help the user to see what's on screen. The user can also save preferred settings so that each of the phone's features and apps use the customized settings as per the user's needs.

Visible and Vibrating Alerts: provides alternative visual and vibrating alerts for incoming phone calls, new text messages, new and sent mail, and calendar events. One can set an LED light flash for incoming calls and alerts or have incoming calls display a photo of the caller. The user can also choose from different vibration patterns or create their own. This can be useful for someone with a hearing impairment.

Mono Audio: allows to play both audio channels (left and right) in both ears when using headphones. This means that the user doesn't miss any audio if he/she is deaf or hard of hearing in one ear.

Closed Captions: allows to watch movies, TV shows, and podcasts with closed captions. The user can customize captions with different styles and fonts.

Switch Control: allows the user to navigate your mobile device using a variety of Bluetooth-enabled switches.

Guided Access: allows to disable the 'home' button and restrict access to the keyboard or touch input on their mobile device so the user stays focused on one app. It also allows to limit the amount of time spent in an app. This may help people with attention and sensory challenges to stay focused on one task.

Apple has been the pioneer in accessibility for smartphones and tablets but some of the Android operating systems have started to catch up. Below described are details of some of their accessibility functionality.

Android Operating System (Android)

The Android operating system developed by Google is used on a range of different devices including smartphones and tablet PC's from Samsung, Acer, LG, HTC, Motorola, Sony Ericsson etc. Therefore it does not have as many integrated accessibility features and not all phones using the Android operating system will have all the accessibility features listed below. If the phone does not have any of these features, one can download them for free in the Android App Store.

Talkback: is a screenreader that provides spoken and vibration feedback to describe user's actions on the phone or Tablet, such as when an app is launched, add an event or make and receive calls etc. Soundback, Kickback and Explore by Touch are included in Talkback for devices using Android 4.0 or higher or for older devices are featured separately in the device's accessibility section. Soundback lets you assign sounds to alert the user to actions on their phone, Kickback provides vibration feedback when one performs actions on the phone and Explore by Touch uses speech to describe each item that the finger moves over on the screen.

Voice Access: allows the user control the Android device through voice. Using spoken commands, one can activate on-screen controls, launch apps, navigate the device and edit text using voice rather than touching the screen. This feature requires Android 5.0 or higher to run.

BrailleBack: allows blind users to connect a refreshable braille display to their Android device (via Bluetooth) so screen content appears on the braille display. Then the blind user can navigate and interact with their device using the keys on the braille display. One can also input text using the braille keyboard. BrailleBack works with the TalkBack screen reader service to provide a combined speech and braille experience.

Switch Access: let's the user interact with their Android device using one or more switches. This can be helpful for users with mobility limitations that prevent them from interacting directly with the Android device. This feature only applies to devices running Android 5.0 and higher.

Captions: allows the users to turn on closed captioning for some functionality on their phone. This feature may allow the user to see the words in text as they are being spoken in certain apps. One can set the language, text, and style for the closed captioning to suit their needs. Requires Android 4.4 and higher to run.

Magnification Gestures: allows the user to temporarily magnify the screen of their device. When magnification gestures are enabled, one can magnify, pan, and zoom in using a range of different gestures.

Large Text: increases the text size on one's device to the largest available size.

High Contrast Text: fixes the text color as either black or white making text easier to read on one's device. This feature runs on Android 5.0 and higher.

The other operating systems for mobile devices such as, Windows Mobile OS and Blackberry OS are not as widely used and do not have as many accessibility features as the two main OS systems above, but they are all working on improving accessibility in newer versions of their operating systems.

Things to Consider Before Purchasing/Downloading an App

Though smartphones and tablets have some integrated accessibility functions, it is the apps (applications) one download that can transform them into a personalized AT device to help them live more independently. There are over four million apps currently available as free or paid.

Some apps (whether intentionally or accidentally) can be of huge value to people with disabilities but some apps can also potentially exclude them. For example, app accessibility is very mixed, with some apps being extremely inclusive and others being completely inaccessible. App developers need to think about accessibility when developing their apps to help ensure accessibility and inclusion. Some other issues with apps that one may need to consider in advance of purchase include:

- Some apps are developed by a parent or family member so they have one end-user in mind, therefore they may not suit a wider market/everyone
- Some apps cannot be edited or customized.
- Some apps are only available for download in certain countries
- Some apps are subscription based
- Voice and picture quality can vary
- Some apps may not be compatible with older devices using older versions of operating systems.

It can be quite overwhelming looking for an app as there are so many available, so it is worthwhile getting advice on what might best suit user's needs. A Speech and Language Therapist or an Occupational Therapist (OT) may be able to advise the user on this, but as apps are a relatively new area, some of them may not have information required. One could also look at specific organizations like Mada, QSCCB, Shafallah, Ihsan, etc.

Apps for People with Visual Impairments

Having a camera on a phone or tablet PC can be very useful for people with visual impairments because there are apps available that allows the user to take a photo of text and the app can read it aloud or magnify it. There are also a range of identification apps that will recognize and speak aloud the color of an object, value of a note or type of object. One can also download screen reading apps and voice recognition apps.

Magnification Apps

Magnification apps are designed to give a magnified image on the smartphone or tablet screen. Some of these magnification apps work best on newer versions of smartphones which have enhanced autofocus cameras. These are just a taste of some of the magnification apps that are available. To browse through them all you will need to visit the Apple or Android app stores.

Magnifying Glass with Light (iOS): app that uses the phones camera to transform iPhone or iPad into a full screen lighted magnifying glass.

Magnifying Glass Flashlight (Android): app that uses the phones camera to transform Android device into a lighted magnifier.

Big Magnify (iOS): magnifying app that uses the devices camera to enlarge items. App has range of magnification options and freeze image functionality.

Magnifier (Android): magnifying app that uses the devices camera to enlarge items. App has onscreen zoom, lighting controls and freeze image functionality.

Best Magnifying Glass (Android): app that uses the device's camera to magnify text or images.

Big Names (iOS): an app that enlarges contacts list in an extra-large font so it is easier to see when dialing numbers.

Big Launcher (Android): an app that allows user to customize home-screen with big buttons and large fonts that represent the phones main functions.

Color Identification Apps

Apps that use the camera on your phone to identify and speak the name of the color in front of the user.

- Color ID (Android & iOS)
- Color Detector (Android & iOS)
- Money Identification Apps

Apps that use of smartphone camera to identify the value of a note. Point the camera at the note and the app will then speak aloud the notes denomination or vibrate to indicate its value.

Looktel Money Reader (iOS): recognizes currency and speaks the notes denomination. Supports 21 different currencies including the Euro, GBP and US Dollar.

Money Talks Euro (Android): uses the devices camera to recognize and read out the value of the Euro banknote.

Object Identification Apps

Apps that use a smartphone camera to identify objects. Some of these apps use a photo library and/or a bar code scanner to identify objects. They will then speak aloud the type of object in the photo.

LookTel Recognizer (iOS): app that speaks aloud the description of an object. The user creates a photo library by photographing items and recording descriptions. Once an item is entered into the database, hold the camera in front of the item and the app will speak the recorded description. The app also has a bar code scanner, which speaks the name of the item when one scans the camera over the barcode.

Ideal Item Identifier (Android): app that reads aloud product descriptions when the user takes a picture of the barcode.

ScanLife Barcode and QR Reader (Android): app that uses the camera to identify objects using barcodes. Once the codes are scanned, the application starts reading aloud the product details.

VizWiz (iOS): an identification app that uses crowd-sourcing. The user can take a picture of an item, record a question and then send the photo and question to their choice of anonymous web volunteers, IQ Engines, Twitter followers, Facebook friends, and/or an e-mail contact. Answers are returned to the app and are spoken as they appear.

TapTapSee (iOS): identification app designed to help the blind and visually impaired identify objects they encounter in their daily lives. Double tap on the screen to take a photo of anything and hear the app speak the identification back to the user.

Light Identification Apps

Light Detector (Android & iOS): app that converts light levels into audio tones, so someone who is blind can detect if a light is on or off. The app uses the phones camera to identify the light source and emits a high or low pitched sound depending on the intensity of the light.

Seeing Assistant - Light (iOS): app that uses the phones camera to identify a light source. The app emits a continuous sound during operation but the tone of the sound gets higher depending on the intensity of the light.

Free Motion Light Detector (Android): app that detects changes in light or movements that occur around the user by emitting a beep or vibration. Depending on the level of change the beep tone and duration of the vibration will vary.

Scan and Read Apps

Text Detective (iOS): app that uses the camera on the smartphone to turn images of text into plain text, which can be read with VoiceOver using speech output or Braille.

KNFB Reader (iOS & Android): print-to-speech app that uses the phone’s camera to take pictures of printed material, convert the pictures into text and then read the text aloud. Recognized text may also be read using a connected Braille display.

Prizmo (iOS): app that allows users to scan in a text document and have the program read it out loud.

Text Fairy (Android): app that takes a photo of a document and converts it into a text document that one can listen to by activating the text-to-speech feature.

Screenreading Apps

Most smartphones may already have a screen reader built into their operating system, for example, Apple's VoiceOver or Android's Talkback. But there are also a number of screen reading apps that can be downloaded.

Classic Text-to-Speech (Android): app that reads out texts, e-books and provides navigation in a choice of forty female and male voices.

Voice Dream Reader (iOS & Android): app that reads out articles, documents and books on a smartphone or Tablet. Available with a range of voices and languages.

Voice Brief (iOS): reads aloud a range of notifications from smartphone applications including calendar, weather app, good reader, email and social media apps.

Voice Recognition Apps

These apps allow the users to use their own voice to navigate between applications, write texts or make calls on their phone. Most smartphones may have some of this functionality built-in, for example, Siri on iOS but these following apps may offer greater control and customization.

Dragon Dictation (iOS): a voice recognition app that allows the user to speak his/her text or email rather than typing it.

Dragon Mobile Assistant (Android): app that allows the user to use his/her own voice to send and receive text messages, post social media updates, write emails and browse the internet.

Assistant (Siri Alternative) (Android): app that allows the user to use his/her own voice to navigate around his/her phone. The user can also use voice commands to send emails, dial his/her contacts, set alarms, reminders and listen to music etc.

Location and GPS Apps

Many smartphones now have built-in GPS receivers that are sufficient for navigation. The built-in navigation in Android is based on Google's map, with driving and walking directions available. Android will use the built-in text-to-speech on the phone to speak turns as they are approaching. There is also a range of downloadable apps available that use GPS to lets the user know where he/she is and what services, businesses or points of interest are in the area. The apps speak this information aloud and can be customized so the user can only hear what he/she requires, for example, a coffee shop on his/her route. As these apps are dependent on GPS mapping, some areas may provide more extensive information than others. Examples of such apps include:

Sendero GPS LookAround App (iOS & Android): app that speaks one's location, what direction he/she is facing and what points of interests are around when he/she shakes the phone.

Ariadne (iOS): app that tells one's position and allows the user to monitor it while walking, telling street numbers or street names. The user can also save favorite locations into the app and be alerted when approaching one of them. This can be alerted with a sound, vibration or a voice.

BlindSquare (iOS): app that finds one's location using Apple's GPS then looks up information about his/her surroundings. By shaking the device, it speaks one's current address and details of the venues around.

Get There GPS (Android): app that tells one current location and how to get at the desired destination. It talks to the user before and after every intersection and update the user to its current location by shaking the phone.

Around Me (Android): app that identifies the user's position and shows a list of the businesses around and the distance to them in a range of categories such as banks, hotels, restaurants, hospitals etc.

Reading Apps

There are a range of apps available for people with a visual impairment to help them enjoy books on their mobile device. There are a range of audio book apps that allows the user to download and listen to audio books on their smartphone or tablet. One can also download apps to listen to Digital Accessible Information System (DAISY) audio books. A DAISY book is a set of electronic files that include audio narration, text marked with special navigation tags, and other files that synchronize the text with the audio.

Audible (iOS & Android): app that allows the user to download audio books and listen to them on the device.

Pastime Audiobook and Podcast Player (iOS): app that plays audio books and podcasts and can be controlled by the user's gestures. Pick an audio book or podcast from the iTunes library, then tap the screen to play or pause it and use swiping motions to fast-forward or rewind it.

Read2Go (iOS): accessible DAISY player app for Apple devices. Allows the user to customize font size, font color, background color, highlighting color, and text-to-speech preferences.

Darwin Daisy Reader (Android): an app that reads DAISY audio books. Allows the user to navigate the app using the arrow keys and all menus are vocalized. One can customize the font and background color, text size, font spacing, voice speed and punctuation speech.

Braille Apps

For people who are used to using Braille, there are some apps available that teaches Braille and ones that allows the user to type in Braille on their touchscreen. BrailleBack comes as a standard feature on some newer Android devices but can also be downloaded to Android devices that don't have it. It allows the user to connect a refreshable braille display to his/her Android device (via Bluetooth) so screen content appears on the braille display. Then the user can navigate and interact with his/her device using the keys on the braille display. The user can also input text using the braille keyboard.

BraillePad (iOS): app that allows user to write text messages, emails and social media updates on their device using Braille. To insert a letter, the user needs to touch each Braille point it is composed of on the device's screen.

iBrailler (iOS): app that allows user to use Braille to access and use his/her Apple device. The app positions the Braille touch keyboard underneath the user's fingertips, no matter where they set them on the display.

Super Braille Keyboard (Android): app that allows user to use Braille to access and use his/her Android device.

Braille Tutor (iOS & Android): app where one can learn to read and write Braille.

Access and Other Apps

Fleksy (iOS & Android): an app which allows user to type text on a touchscreen without even looking at it. It has a QWERTY keyboard layout with auto-correct and predictive text that mean one can type every letter in a sentence wrong and it will still predict the correct sentence

Be My Eyes (iOS): app that connects blind users to a group of sighted volunteers who they can video chat with when required. The sighted person can tell the blind person what they see when the blind user points their phone's camera at something.

List Recorder (iOS): app that records voice and text notes so one can make lists or notes using their own voice.

Video Motion Alert (iOS): app that detects motion by using one's phone camera. The user will aim the phone's camera at the space he/she would like to monitor and an alarm will sound if motion is detected.

Apps for People with Hearing Impairments

There are a number of different apps available for someone with a hearing impairment. For example, video-calling means that people can use sign language over the phone to communicate. There are also captioning apps which can 'text caption' a phone call so one can read anything they did not fully hear during the conversation.

Texting Apps

Texting is also an important tool for people who are deaf or hard of hearing, there are a number of messaging apps that allow you to text, send photos or video's to other people or groups of people using the app. These apps are useful as they are normally free to use as long as you have internet access. Such apps usually tend to be considered mainstream nowadays – e.g. WhatsApp, Viber, Facebook Messenger, and Snapchat.

Video Calling Apps

Video-calling on a phone can be very helpful for someone with a hearing impairment as it allows the user to see the caller using sign language. Your phone may already have video calling built into its operating system, for example 'FaceTime' on iOS. Some of the apps below may also be of use, remember that you will need a camera on your device to use these apps and may also need Wi-Fi. Similar to texting apps, video calling apps also tend to be considered mainstream nowadays – e.g. Skype, Viber, Facebook Messenger, and Glide

Amplification Apps

Amplification apps increase sound and send it directly to one's ear blocking out background sound.

Usound (Hearing Assistant) (iOS & Android): app that amplifies sound so that people with hearing impairments can use it with earphones to hear conversations, movies and TV. The app initially does a hearing test to assess the user's hearing difficulties and customizes the amplification to his/her needs. The amplification can also be adjusted for different situations.

Hear You Now (iOS): app that amplifies sound so that people with hearing impairments can hear conversations in noisy environments or listen to TV and movies. The amplification level can be adjusted to suit the user's needs or the situation.

LouderTV (iOS): a personal amplifier app that increases TV sounds for people with hearing impairments. The user needs to plug his/her headphones into the phone and the app will send what is being said on the TV straight to his/her phone at an increased volume level.

Captioning Apps

Hamilton Captel (iOS & Android): a captioning app that captions what is being said on a phone call, so one can read the bits he/she miss.

Clear Captions (iOS & Android): app that adds captions to the user's phone calls so he/she can hear and read what's being said.

Subtitles Viewer (iOS & Android): an app that provides subtitles on the phone so the user can play it along with a TV show or movie and read the subtitles on his/her phone screen. The app only displays the subtitles on the user's phone.

Live Caption (iOS & Android): app that provides captions for face-to-face conversations. The user's conversation partner speaks into his/her smartphone and the app uses voice recognition software to transcribe the words onto the device's screen.

Alternative Alert Apps

Allows to translate audible alerts to visual or vibration alerts.

TapTap (iOS): app that listens and detects warning alarms like fire alarms etc and vibrates to alert the user of an alarm.

MyEarDroid - Sound Recognition (Android): app that identifies sounds in the home such as the door-bell or alarm clock and alerts the user to the event by vibrating or flashing. One can record a range of different sounds that he/she want the app to recognize around the home.

Otosense (iOS & Android): app that detects noises around the home such as the doorbells and fire alarm and alerts the user through text and vibration alarms. The app is pre-programmed to recognize standard smoke alarms but can also be customized to other alarm sounds at home.

Voice Recognition Apps

Dragon Dictation (iOS) & Dragon Mobile Assistant (Android): speech-to-text app that allows someone to record their speech and have it converted to text so that someone with a hearing impairment can read it. Dragon will transcribe the words as the person is speaking so there is no delay in communication.

Speak 2 See (iOS): speech-to-text app that uses voice recognition software to convert words into large text on screen.

Note, Listen (iOS): app that allows the user to makes notes for a hearing person, then when they reply the app converts their words into text on screen using voice recognition software.

Note, Speak, Listen (Android): app that allows the user to makes notes in large text on the device's screen for a hearing person, then when they reply the app converts their words into text on screen using voice recognition software.

Sign Language Apps

Spread Signs (iOS & Android): sign language dictionary with over 300,000 signs from a range of different countries.

Apps for People with Communication Difficulties

Apps to help with communication have made a huge difference to people with communication difficulties. Stand-alone AAC devices are hugely expensive compared to a smartphone/tablet and a communication app, which are cheaper and in most cases a lot more portable. Also many of the well-established AAC software companies have brought out app versions of their software, so people can move to a smartphone/tablet but keep the communication software they are used to. This AAC app area is constantly growing, so below is just a few of the most popular apps in this category.

Apple has been the forerunner in AAC apps, so many of the most popular communication apps are only available on iOS at the moment.

Single Message Apps

TapSpeak Button(iOS): app that turns your device into a single message communication device. You can record a number of messages and store them, then play the one you want when you press the image of a button onscreen.

AAC My Message (Android): one-message communication app that allows you to record a message and play it back by pressing on the screen.

Sequenced Message Apps

TapSpeak Sequence (iOS): iPad app that allows the user to record and playback customized sequential messages. The user can tell a story by recording different sequential sentences/phrases and playing each one back every time he/she press the onscreen button. The app contains the DynaVox/Mayer-Johnson PCS image library so the user can choose one of these icons/images to represent what he/she have recorded instead of a button image.

Visual Scene Display Apps

Scene & Heard (iOS): app that enables Apple device to function as an alternative and augmentative communication (AAC) system. The user can build scenes and vocabulary by taking photos with the device or importing from its photo library, then recording voice messages for scenes to ask questions or share stories. The app contains over 10,000 Widgit symbols.

Apps for Whole Message Buttons

TapToTalk (iOS and Android): communication app that displays a set of pictures onscreen. When the user taps a picture, the app plays a word or sentence and then displays another or follow-on screen of pictures relevant to the topic. Each set of pictures can lead to another related screen, and so on. For example, a picture representing Food can lead to a screen with pictures of Fruit, Vegetables, Sandwiches, Snacks and other foods.

iComm (iOS): this communication app uses words (both written and spoken) and personalized pictures for communication. It organizes pictures and their descriptions into nine categories, and pictures can be added, edited or changed to the user's needs. The program includes pictures needed for everyday communication such as "yes","no", "more" and "finished."

Apps for Sentence Construction

Alexicom AAC (iOS & Android): app that can be used as a stand-alone AAC system. The user can create and edit grids using images from his/her gallery and then use synthesized speech to read aloud sentences and descriptions. The app supports switch access, scanning and bluetooth for remote access to the device. It also provides text-to-speech and word prediction.

Sounding Board from Ablenet (iOS): app that provides pre-loaded communication boards with symbols and recorded messages to allow communication for those who have difficulty speaking. The user can also create their own customized message boards. This app can be accessed by switch scanning for those who cannot touch the screen.

Apps with Symbols and Text to Speech

AutoVerbal (iOS): AAC app that allows the user to communicate in three different ways. One can use built-in phrases which are divided into different categories, the user can program buttons to speak customized messages, or type words or sentences which can be spoken using text-to-speech.

Sono Flex (iOS & Android): AAC vocabulary app that turns symbols into clear speech. App comes with 50 context vocabularies and 11,000 SymbolStix® symbols. The app can be customized and has a choice of voices.

Prologue2Go (iOS): AAC app that allows the user to create onscreen icons to be pressed to generate sentences which are spoken aloud.

Apps for People with Alzheimer's or Dementia

There is a range of apps available to help people with dementia live more independently, including medicine reminder apps, apps that alert a carer if the user falls or wanders as well as reminder apps that alert the user to complete or undertake a task.

Pill Reminders

These apps remind the user when his/her medication is due to be taken. Some of these apps provide an audible reminder when one need to take his/her medications, while others can provide a visual alert. Pill reminder apps will not work if the phone has no signal, on silent, or if the phone's battery runs out.

Pill Reminder (iOS): app that alerts the user when to take his/her medicine or refill a prescription. The app has a range of audible alert sounds including an extra loud reminder which may be useful if someone has hearing difficulties. The app has a built-in database of medicines so one can also access information like dosage and side effects of medication. It lets the user add photos of his/her medication so it is easy to recognize even if the writing on the packets is small. The app also keeps a history of when medications are taken or missed.

MedCoach (Android & iOS): app that helps the user remember to take his/her medications and pills. It can be set up with multiple alarms, log the pills taken, and there are automatic reminders when its' time to refill prescription. The app links through to a medication database that provides information on medicines.

Fall Detection Apps

These apps are designed to alert a carer or family member if the user has fallen over.

iFall (Android): app that uses the phone's accelerometer (measures force and acceleration) and tries to detect when a fall has occurred. If a fall is detected, the user is issued a prompt which gives them a chance to clear if it is a false alert. If the alert times out without a user response, their emergency contact is called.

Fall Alert (Android): app that triggers an alarm if the user falls, sending an automatic SMS or phone call to the user's designated number. GPS coordinates will be attached in the SMS message. It is also possible to activate the function by pressing the 'Panic' button in the app.

Fall Detection (iOS): app that uses the phone accelerometer to detect if the user have a fall. If a fall is detected an email or text message is sent to the user's designated recipients, providing his/her GPS location and street address.

Wander Apps

These apps are designed to alert a carer or family member if the user wanders off, becomes disorientated or gets lost.

iWander (iOS & Android): an application that utilizes GPS and other locating technologies to identify the location of smartphones on which the app is installed.
Reminder Apps

It's Done! (iOS): this reminder app helps confirm if the user have completed tasks throughout the day. The It's Done! app confirms that the task has been completed. The app can also send a text message or email to others when a task is done, so family or carers can be at ease that the oven has been turned off etc.

Apps for People with Autism & Other Related Disorders

There is a range of educational apps available for children with autism or developmental delays, which are detailed below. It can also be worthwhile looking through the App Store for the things that the user is interested in and use those apps as learning tools. For example, if the user is interested in trains, one could download a train timetable app to help them learn times etc.

Communication Apps

There is a range of apps available to help people communicate independently. These include basic communication board type apps, where the user points at a picture on their device to explain what they want, right up to more advanced communication apps that construct sentences and have text-to-speech capabilities. Below are the examples of such app:

Grace (iOS): communication app designed to help people communicate their needs independently. The user selects pictures to form sentences which they then share by pointing at the card on the device to hear the listener read each word. The app does not use speech but is designed to encourage the user to attempt their own vocalizations. It comes with a basic vocabulary of pictures, but it can be fully customized using the device's camera or images saved from the internet.

Autism Speech Diego Says (Android): app designed to aid basic communication. The user pushes the action button 'I want' and then presses one of the next possible options for example 'food'.

iConverse (iOS): app with six display icons that represent a person's most basic needs. When activated, the icons give an auditory and visual representation of the user's specific need.

Organizing/Scheduling Apps

First Then (iOS & Android): visual scheduling app that lets the user create and display daily events or the steps needed to complete specific activities using images. The schedules can be customized to the needs of the individual.

iPrompts (iOS & Android): visual scheduling app that allows the user to display picture sequences to guide the user through different activities. Schedules can have many pictures, and captions can be edited for each image.

Pocket Picture Planner (iOS): visual scheduling app that reminds the user of daily events and tasks you need to complete. It provides information and instructions for each task. The user can associate visual and audio media files with a task or event and the app also provides pop-up reminders when activities are due.

Behavioural Apps

Life Skills Winner Pro (iOS & Android): app that teaches life and social skills using positive feedback. It breaks down life skills into steps, for example brushing one's hair. It emphasizes the importance of the skill as well as incorporating an interactive aspect like using the touch screen to drag the brush across the character's hair. These actions allow the user to earn designated points to collect and 'cash in' for a reward.

iReward (iOS): app designed to reinforce a certain behavior by providing motivation and a reward, for example, a gold star, a new toy etc.

Easy Kid Tokens (Android): app that rewards good behavior. The app has a behavior chart with images representing the reward the child is working toward. The child receives 'stickers' or 'tokens' for good behavior, receiving a reward when they reach the number of tokens needed. The app also plays music when the child has reached their reward.

Listening and Attention Apps

Simon Says (iOS): attention and concentration app. The goal of the game is to remember the sequence of buttons selected and repeat them in the same order. The user can choose from images of animals, cars, musical instruments, colors or shapes etc.

Animal Memory (iOS & Android): concentration and matching app where the user have to pair up pictures of animals. The game has a number of difficulty levels and the animals make noises to keep children entertained.

Concentrate (iOS): app that displays work and break time in a graph on the device's home-screen. This allows the user to focus work and be efficient.

Cause and Effect Apps

Cause and Effect Sensory Light Box (iOS & Android): app that provides visual effects when the user press or sweep over the screen. The app encourages development and basic awareness of touches and gestures.

Bubble Explode (iOS & Android): app that provides visual and auditory effects when the user press the screen. The aim of the game is to explode the bubbles onscreen by touching them.

Apps for People with Mobility Difficulties

Home Automation Apps

There is a range of home automation apps that allow users to control their environment using smartphone or tablet. These apps are often part of a home automation system, it requires a smartphone that can 'talk' to the system or the device preferred to operate remotely before downloading the app. Home automation means that the user can turn on, for example, a light, the heating, or open the curtains remotely. To do this, the user have to set up an automation system in the house which allows these devices to be controlled by phone through wifi, infrared etc. Alternatively the user can use infrared/wifi sockets to allow his/her phone to communicate with, for example, a lamp or music system.

There are also an increasing number of apps for smartphones and tablets designed specifically for the mobility impaired. For example, the Open Sesame app for Android devices uses computer vision technology to allow someone to access any app on their smartphone or tablet by simply moving their head. Users with limited use of their hands can Tweet, post to Facebook, send instant messages, make phone calls, or download any of the other millions of apps available use them touch-free.

Robots & People with Disabilities

Robots are still in early stages of development in terms of interaction with humans and deployment in uncontrolled environments – however, rapid progress is being made in these domains which mean they are on the cusp of becoming viable to be used for assistance and companionship for older and disabled people. Robots have considerable potential to support elderly and disabled people. However, this potential does not seem to have been realized in practice. For instance, only 159 assistive robots for disabled and elderly people were sold worldwide in 2012. This is likely to be an underestimate, as a number of the systems in use are non-commercially available prototypes that do not appear in the statistics.

However, even taking this into account, it is a very small number compared to the 1.96 million household robots, including vacuum and floor cleaners and lawnmowers, sold in 2012. It is projected that about 6,400 assistive robots will be sold in 2013-2016 and that substantial expansion will take place over the following 20 years. However, it should be noted that assistive robots are generally much higher technology products than household robots. They are therefore often correspondingly expensive, and this higher cost will affect their use. Assistive robots are a type of personal service robot. Together with industrial and professional service robots, this is one of the three main categories into which robots have been divided.

Drawing on a definition of assistive technology and the definition of service robots given above, an 'assistive service robot' can be defined as an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform tasks and services which are used by disabled and/or elderly people to overcome social, infrastructural and other barriers to independence, full participation in society and carrying out activities safely and easily. Work on assistive robots started in the early 1960s and has intensified over the past 15 years or so, partly due to advances in technology. While a number of useful assistive robots have been developed, many projects have not gone beyond the prototype stage and others have not even produced prototypes.

The main division of assistive robots is into socially assistive robots, which, for instance, act as companions and toys, and physically assistive robots, such as robotic wheelchairs, smart homes and manipulators. However, it should be noted that, while useful, this division is not always clearly defined. For instance, many of the prototype robots designed for elderly people have both physical and social assistance functions. In addition, devices such as robotic guides for blind people do not really provide either social or physical assistance. Therefore, two further categories will be defined: sensory assistive robots and mixed assistance robots.

A further three categories could be defined on this: robotic organs and limbs, telemedicine and health monitoring and design for all. Robotic limbs and organs e.g. they are better classified as rehabilitation robotics rather than assistive service robotics. One of the main distinguishing factors is the difference between external robots which may interface with the user and robots which become part of or are directly attached to the user's body. Design for all personal service robots are personal service robots, including the increasingly popular domestic vacuum cleaners and lawnmowers, which have been designed in accordance with design for all (universal design) principles.

Design for all involves making products and services, such as robots, accessible and usable by as wide a range of the population as possible, regardless of factors such as age, gender, disability, size, culture and class. It should be considered part of standard good design practice. In the case of robots, appropriate design of the human-machine, in this case the human-robot, interface, is particularly important. This is the means by which the user gives instructions to or operates the robot and receives feedback from it. This may require the robot to have a wider range of input and output options than is commonly the case and/or to be compatible with assistive devices.

Classification of Assistive Service Robots

The types of assistive service robots which have been developed will now be presented using the four-class categorization presented below. This categorization will be in order with physically, sensory and socially assistive and mixed assistance robots. The assistive robots discussed in the different sections include the following:

Physically assistive robots

❖ Robotic Wheelchairs

Significant numbers of people, though only a small percentage of the population, use electrically powered wheelchairs. Powered wheelchairs are generally prescribed for people who do not have sufficient control of or force in their upper limbs to use a manual wheelchair. Wheelchair use involves two types of control: (i) low-level control e.g. obstacle avoidance and keeping the chair centered in a passage; and (ii) high-level control e.g. directing the wheelchair to a desired location. Users with good joystick skills can manage the two types of control at the same time, whereas this may be more difficult for people using other types of input devices and those with limited joystick control, visual and/or cognitive impairments, and/or who tire easily. The addition of environmental and user status sensors and artificial intelligence can increase the range of users.

A robotic wheelchair can assist users by taking over low-level control, such as avoiding obstacles, so that only high-level directional commands, such as forward or stop, are required. A degree of shared control has been shown to help users avoid accidents. An appropriate balance of control is required, with users generally wanting control over high-level command functions, such as the destination, as well as the ability to vary the wheelchair's level of autonomy. Robotic wheelchairs should be fully compatible with a wide range of input devices. They also need to be highly reliable, robust, physically safe for users, and fault tolerant. Smart wheelchairs have been developed since the 1980s. It should be noted that the terms 'smart' and 'robotic wheelchair' are both used in the literature, and that wheelchairs which provide smart functions meet the definition of robots.

Currently available robotic wheelchairs and prototypes offer assistance with different combinations of the following functions:

- Obstacle and collision avoidance
- Going through narrow openings, including doorways and between pillars, and maneuvering in tight corners
- Route following and landmark based navigation
- Going up and down stairs and slopes

- Traversing narrow hallways or passages, by following the walls or staying in the center of the hallway or passage.

The features which can be used to classify smart wheel- chairs include the following a basic design approach, input methods, types of sensors, control software, operating modes and whether the wheelchair is commercially available. There seem to have been three main approaches to the design of smart (robotic) wheelchairs.

Early smart wheelchairs, such as VAHM and Mister Ed, were mobile robots with added seats. The majority of current smart wheelchairs, including NavChair, OMNI, MAID and SENARIO, are commercial powered wheelchairs, with significant modifications. The third option, which has only been applied in a few cases, such as SWCS, Hephaestus, TinMan and Siam, involves a package of software for smart control functions and sensors which has been designed to be compatible with a number of wheelchairs to which it can be added. This has the advantage of enabling users to access smart functions from their existing wheel- chair, thereby reducing costs and ensuring appropriate seating with good comfort and support. However, it has the disadvantage of not being fully integrated with the wheelchair, and this prevents the user's input being fed directly to the processor of the wheelchair's motors without requiring reverse engineering.

One approach to shared control involves combining the shared control module with a dynamic local obstacle avoidance module in a hierarchical manner. The user indicates their intentions via a joystick, but the signal may be altered by the collaborative controller, obstacle avoidance module or virtual bumper based on a laser scanner and sonar readings, before being passed to the motor control unit to be executed. Reduced speed can be used to increase safety and make the control movements and the ride smoother, but there are arguments for allowing the user to determine the speed (within the limit of what is possible for the particular wheelchair).

- **Robotic manipulators for reaching and lifting, personal care, eating and drinking**

Appropriately designed robotic manipulators can increase the independence and quality of life of people with motor impairments. In particular, they can support people with limited hand

and arm movements, including those with high-level spinal injuries or tremors. However, it is important that the availability of these devices is not used to reduce the availability of personal assistance, as contact with personal assistants is important to many disabled people. The earliest devices were large, complex and not very attractive, whereas subsequent developments have resulted in smaller, cheaper and more attractive devices. While safety has improved considerably, avoiding risk to users is still a very important consideration.

A number of surveys have identified that disabled people in this group would like assistive devices for carrying out the following activities:

- Eating and drinking
- Personal care, including washing, shaving, applying cosmetics or scratching an itch
- Handling papers, books, cds and videos
- Mobility and access, such as opening room and cupboard doors, and operating light switches and lift buttons
- General reaching and moving tasks, including reaching up to get an item off a shelf or from a cupboard, and reaching down to pick up an item from the floor, and moving items.

Robot manipulators have been categorized as follows:

- Workstation or desk-based systems in fixed position, including MUSIIC, Raid and ProVar
- Wheelchair-mounted manipulators, which include MANUS and Raptor
- Mobile robot systems, including ARPH

All the categories can be further divided into multi-task and single-task robotic manipulators, though most of the single-task manipulators are stationary. All the different types of devices have their applications, as well as advantages and disadvantages. Fixed workstations have the advantages of reduced complexity and price, using standard robots and pre-programmed motions to speed up task execution, but the disadvantage of only being able to access a limited volume of space, though the use of longer robotic arms can increase this volume.

These robots are best suited to workplaces where speed is important and only a relatively small number of different tasks are carried out. They are likely to be more useful for work-related workstation- or desk-based activities than household activities, which generally use different rooms. The control system has information about the objects, such as books, computers and cups, in the immediate environment of the manipulator, and the user can use pre-programmed functions to pick up and move objects. The robot can also operate in partially unstructured environments.

Wheelchair-mounted systems have the considerable advantages of being mobile and always being with the user, and wheelchair-mounted multi-function devices are the most flexible. However, restrictions on manipulator size result from the requirement of not significantly increasing the wheelchair width in order to allow it to go through doors. The appropriate length for the arm depends on what the user wants to reach, but can generally is shorter than for a fixed station. End-users generally want to be able to control objects in an unstructured world e.g. a cup in an arbitrary position on a table as well as objects such as doors in predefined positions. This is a difficult technical problem.

The following two approaches have been used to address this challenge:

1. The end-user identifying objects and guiding the manipulator to them
2. Using sensors to obtain information, sensor fusion techniques to extract data and special control algorithms to manipulate the identified objects.

Systems in the second category are fairly complex and expensive. Autonomously mobile systems have some of the advantages of wheelchair-mounted systems and can also be sent to areas the user cannot reach, for instance when in bed. However, they require greater on-board intelligence and autonomy. They include relatively low-cost trolley mounted systems, which require another person to move the trolley-based system between rooms.

Feedback from users indicates that they want greater functionality and a remote controlled powered system or for the robot to be mounted on the wheelchair. Important factors to take account of in the design include aesthetics and the attractiveness of the device, reliability and safety, steering and wheelchair usability. The device’s appearance and attractiveness are important both because the user will generally spend a considerable amount of time with the device and because it may affect the way other people react to and treat them. In particular, attaching a manipulator to a wheelchair can have a significant visual impact. The user should be the center of focus, rather than being hidden behind a lot of gadgets, and the manipulator should be attractive, as unobtrusive as possible, and aesthetically integrated with the wheelchair in terms of shape, style and color.

Very high reliability is essential, since users will frequently be dependent on the manipulator and any malfunctions could have a serious negative impact on them. Reliability should include not compromising the control, usability, steering or stability of the wheelchair, for instance as a result of the size, weight and positioning of the robotic arm. In addition, vibration when the manipulator makes contact with an object should be minimized. The arm should also not negatively affect seat adjustment, pressure relief and transfer to and from the wheelchair. It should also have low power consumption and be able to reach floor level and head height. The barriers to the acceptance of robotic manipulators include concerns about size, insufficient functions, poor appearance, taking too long to carry out activities and fears of becoming isolated and a reduction in communication.

Single-task robots are designed to carry out a particular task, such as eating or washing. They are very useful but cannot be operated in an unstructured environment. They include a number of commercially available robotic feeding devices which have been in use for a number of years. They are generally relatively inexpensive and, in some countries, the cost can be covered by the medical or social security system. Eating devices enable people with high-level spinal injuries to feed themselves, though the food needs to be set up on the system.

Robotic systems may have advantages with regard to non-robotic systems in terms of size, appearance and options for user control. The Mealtime Partner and Neater Eater are both available in North America and Europe, and use a rotating food compartment and plate, respectively. The Neater Eater can be operated by a head control device. It has a modular structure which allows it to be tailored to individual requirements. It includes an arm mounted on a choice of baseboards; foldaway clamps for fixing to a table; high-sided ceramic or plastic turntable plates with pegs designed to fit into the baseboard; and plastic or metal cutlery fitted into a holder that clips to the Neater Eater arm.

The SECOM MySpoon system used in Japan allows the user to select the control mode from fine directional control, compartmental selection mode and automatic mode. It is small, designed to Marion Hersh Overcoming Barriers and Increasing Independence – Service Robots for Elderly and Disabled People be incapable of accidentally striking the user's head, and relatively quick to use.

MANUS (or the assistive robotic manipulator – ARM) is a commercially available wheelchair-mounted general purpose manipulator, which has been sold commercially since 1990 and is used by over 100 people, particularly in the Netherlands and France. It allows users to carry out daily living and work tasks at home, work and outdoors. The following specifications were identified before the start of development:

- Slim, to allow the wheelchair to which it is attached to pass through doors
- Lightweight, to minimize the wheelchair load
- Easy to control with single input devices, such as joysticks and keypads
- Mechanically integrated into the wheelchair, with an integrated manipulator and wheelchair control
- Minimal power consumption.

It has six degrees of freedom, excluding the two-finger gripper which is opened and closed by a passive spring, giving a three-point gripping action for most objects. Gripper accuracy increases with the rigidity of its fixture to the wheelchair, but power loss due to friction and backlash can make it difficult to control the arm precisely. A ball-screw mechanism translates the rotary drive into the linear movement of the gripper. It has a self-breaking effect which ensures that the gripper remains closed in the event of a power failure, preventing objects being dropped and possibly broken.

Sensory assistive robots

❖ Mobility Devices for Blind People

Robotic devices have the potential to be used to support mobility and independent travel for blind and partially sighted people, as well as to provide physical support for, for instance, older blind people. These devices generally have a number of sensors and carry out real-time analysis of the environment and compute and follow an appropriate optimal travel direction that avoids any obstacles in the user's path. The guide changes direction when the robot detects an obstacle and communicates this change to the user by having sufficient mass for the user to feel its movement hectically through the physical interface provided by the device handle.

The user intuitively reacts to changes in direction of the handle caused by the movement of the robot's wheels and is thereby steered along the desired path. This requires minimal training input, where- as specialist training over an extended period is generally required to use a long cane or guide dog safely and effectively. Robotic guides therefore have some of the advantages of a guide dog or human guide in terms of a very intuitive guidance system based on following the robot's movements, while avoiding the need to be responsible for a dog or dependent on the availability of a human guide.

In addition, a robotic guide is much easier to use and requires considerably less concentration than the long cane or devices based on it, and could give blind people who currently only go out when accompanied the confidence to do so without a human guide. It is still essential that blind travelers have a reasonable level of independent mobility skills and that they are in a position to make decisions to override the robotic device. However, the technology is advancing and, at some point in the not very distant future, the development of robotic guides able to support blind people with limited mobility skills to travel safely should be feasible. Robustness and reliability will be very important for this type of robot, and it will be essential that there are numerous backup and failsafe features to reduce the risk of failure to as close as possible to zero.

The availability of robotic guides will significantly increase the opportunities and quality of life of the numerous blind people who currently only travel accompanied, since family, professional and volunteer guides are not always available. They would also be very useful for proficient travelers in unfamiliar environments. Robotic guides could have the further advantages of improving confidence and mobility skills, particularly for blind people who normally travel accompanied.

On the negative side, robotic guides have the disadvantages of relatively high costs, though good design could reduce this, and drawing possibly negative attention to the user, unless very well designed. A recent study found that potential users are particularly concerned about the appearance of a robotic guide and that they wanted it to be inconspicuous, whereas a device of a certain size is required to enable users to feel its movements, for instance to avoid obstacles, so they can easily follow it. Respondents also wanted the robot to either be unobtrusive or to have an attractive appearance. For younger users, a science fiction/robot look might work, but this would probably not be acceptable to older users.

Further desirable features include an adjustable handle and a pointing device to indicate the desired direction of travel relative to the current orientation. A balance is required between the robots being light and compact so as to make it easily portable and to facilitate lifting onto public transport, and the minimum weight required for the user to feel and respond to the robot's movements. The robot should require minimal power to both extend the time it can be used between charges and to minimize battery weight.

A robotic guide could also be designed to incorporate self-defense functions to increase user safety. However, considerable care would be required in the design so as to ensure that they were not used inappropriately and that the use of excessive force was avoided.

- **Shopping Assistance Robots**

Blind people require assistance either from technology or a person to locate and identify products and to read information about them, such as prices and ingredients. Both robotic and software-based shopping assistants for blind people have been developed. The software based systems Blind Shopping, GroZi, iCode, ShopCode, ShopMobile, ShopTalk and Tinetra. These systems detect and identify products using barcode scanners, RFID readers and cameras which read quick response matrix barcodes. The software is installed on, for instance, a mobile or smart phone or a mini PC in a backpack, and some of the systems provide navigation instructions.

These systems have the advantages of being easily portable and of not drawing attention to the user, and are probably considerably cheaper than robot systems. However, robotic applications have the advantage of being able to provide additional functions, such as guidance and support for the user, bringing products to the user and carrying them. RoboCart has two main functions: guiding a blind shopper to the vicinity of a product, and haptic exploration to find the product supported by the locomotor and haptic modules, respectively. It consists of a mobile robotic base with a wayfinding toolkit in a PVC pipe structure which also provides a handle, and a basket mounted on this structure. The rigid handle provides haptic feedback about the robot's movements. A 10-key numeric keypad in the handle allows the user to browse a list of products or enter a product number. When the shopper is close to the product, the robot tells them how to find the product in synthetic speech using their egocentric (body-based) frame of reference.

The robot uses Monte Carlo Markov localization with RFID mat recalibration points read by an RFID antenna close to the floor. The need for RFID mats is one of the disadvantages of the device. Comments from participants in user tests indicate that they want to know what products they are walking past, with more detailed information on how to find the product after scanning the barcode, and for the robot to stop either directly in front of or just past the product (depending on the presence of other shoppers and other obstacles) and beep rather than make clicking sounds, which are both irritating and easily missed in the background noise. Robotic shopping assistants designed for guiding nondisabled shoppers could be used to support visually impaired people if appropriately modified. However, they are only able to guide users to the approximate location of the products of interest, rather than aiding them in locating a particular product or providing information about other similar products to enable comparisons.

Socially assistive robots

❖ Companion and socially assistive robots

Social robots are designed to produce social behaviors and perceptions in people. They draw on the human tendency to anthropomorphize objects, giving rise to feelings for them, and they proactively engage with people and/or show some degree of social intelligence. Socially interactive robots are a type of social robot for which the social interaction between the human and the robot is particularly important. They may perceive and/or express emotions, use high-level dialogue in communication, recognize other agents, establish and/or maintain social relationships, have 'personality' and 'character', and they may be able to learn social competencies.

Socially assistive robots are a type of social robot which provides assistance to end-users through social interaction. The human tendency to attribute human intentions and goals to even very simple mobile physical entities may make companion and socially assistive robots more effective than a programmed on a computer or mobile phone. A classification framework for social robots based on the following five properties has been proposed:

- Form from abstract through animal-like to humanlike
- Modality or number of communication channels
- Extent of knowledge of social norms
- Degree of autonomy
- Interactivity or extent of causal behavior

Socially assistive robotics support users through social interaction. They are designed for emotional expressiveness, user engagement, appearance and robustness during interaction, in order to assist the user and influence their behavior. Feil-Seifer benchmarks for socially assistive robots are stated below with 'carer' replaced by 'personal assistant', as this has a wider meaning.

Socially assistive robots could have potential benefits for at least some elderly people, but they also raise a number of serious concerns, many of which are summarized. The possible use of deception and diverting attention from possibly serious problems has already been mentioned. Concerns about the substitution of real contact with people by robots, which addresses user acceptance as in the case of the smart house, there is also the potential to use these robots for surveillance and to control an elderly person's activities. As indicated in, there is also the possibility that robots will be used in ways that demean and infantilize elderly people.

There is therefore a need for further research on the use of socially assistive robots in ways. There would also be value in the development of taxonomy of socially assistive robots which relates robot characteristics to user characteristics and preferences, and the specific functions and context in which the robot is used that are acceptable to elderly people and which remain within their control.

❖ Robots for Autistic Children

The use of robots with autistic children is another area which has potential but which could also give rise to problems. Robotic toys to be used by disabled children need to be very robust, and autistic children may prefer a robot without facial features to one that looks human. The investigation of peer-reviewed studies of the interactions of autistic children with robots indicates the potential of robots to elicit various types of behavior, but further research is required. The following robot design specifications have been suggested:

- Approximately the size and weight of a commercial doll, i.e. about 50 cm high and 1 kilogram in weight
- Low cost, to allow purchase by collaborating schools and museums
- Onboard processing and battery operated
- A resemblance to commonly used toys

It has been suggested that a human seeming body and features can bridge the gap between non-human-looking machines with which autistic children feel comfortable and people where the interaction is more difficult. Research is investigating whether social interaction with robots can be translated into improved social interaction with other people e.g. a number of different robots, both research prototypes and (modified) commercially available robots, have been used with autistic children, but their use is still at the research stage.

They include humanoid, generally toddler or small child sized robots animal robots and objects. NAO, Kaspar and Robota are three toddler- or small child-sized humanoid robots. Both Kaspar and Robota are designed to be low cost and generally wear clothes which cover the robotic parts, as well as a wig. NAO is 0.57 meters high and weighs 4.5 kilograms. Its patented pelvis kinematic design only requires one motor and allows it to simultaneously bend forward and move its legs apart. Its sensors include cameras in the head, capacitive feedback to receive ‘tactile’ input from contact, two gyro meters and three accelerometers for real-time data acquisition.

The Choregraphe software provides text-to-speech conversion, sound localization, visual pattern and colored-shape detection, obstacle detection and visual effects, which are output through its LEDs. NAO has 25 degrees of freedom, five in each leg and arm, one in each hand, two in the head and one in the pelvis. Both Robota and Kaspar are designed to be low cost.

Kaspar is a stationary humanoid robot which is ‘minimally expressive’ to avoid presenting too many social cues while providing facial expressions for autistic children to inter- pret. It is the size of a small child with a large head. Its body is based on a child-sized shop floor dummy and its face is a silicon rubber face mask from a child resuscitation practice dummy. It is flexible enough to be deformed by actuators and it provides simplified human features. Kaspar’s main moving parts are the head, neck and arms with the joints activated by radio-controlled model servos.

Robota is a 45 centimeter high humanoid robotic doll weighing 1.6 kilograms and containing a PIC motor, sensor boards and drivers. It can copy some of the user’s movements. Some of the behaviors are designed to be socially expressive. On the one hand, there are indications that robots can be used to support the development of competencies in interaction and communication, and that autistic children are using the robots as a ‘mediator’ to support interaction with the experimenter or other children. On the other hand, there may be attempts at behavior modification in order to try and ‘normalize’ the children rather than focusing on developing innate strengths and competencies, which help them to function in what is often a not particularly friendly world.

Future of Robots

We have discussed of robots that was structured into the three categories of: (i) physically assistive robots; (ii) socially assistive robots; (iii) sensory assistive robots. A more detailed categorization based on assistive technology models has been proposed. The discussion of different types of assistive robots was introduced by an overview of some of the underlying technologies used in assistive robots.

However, this potential is largely untapped with only small numbers of robots in actual use, many projects not getting beyond the prototype stage, and a number of assistive robots being used as platforms for research rather than being made available, commercially or otherwise, to potential users.

The applications discussed are able to support various groups of disabled people in the home or workplace, in leisure activities and in facilitating travel, whether through guidance or the provision of other smart functions. Greater availability of these applications could have a significant positive impact on the lives of disabled people. Although robots may not be suitable for all potential applications, the current application areas seem relatively limited and the examination of the various models of human activities indicates that there may be a wide range of other application areas that have not yet been investigated.

On the other hand, not all potential applications of assistive robotics are positive, and there is a need for assistive robots to be used appropriately. There are probably greater concerns about socially assistive robots than there are about physically assistive robots. However, in both cases there are issues of the substitution of personal assistants by robots rather than the two approaches been seen as complementary and both being available, so that users can make appropriate choices for their particular circumstances. When used appropriately, such robotics applications can significantly improve the options and choices available to potential users. However, the use of personal assistance to carry out self-care tasks may be faster, making more time available for work, study and leisure activities.

In the case of socially assistive robots, elderly people in particular have serious concerns that robots will replace personal contact and personal assistance, leading to a loss of companionship and increasing isolation, though there is also some evidence of these robots providing the focus for increased positive social interaction with other people.

These concerns are very real and need to be taken seriously. Regardless of future technological developments, it seems unlikely that interaction with a robot will ever have the same quality as interaction with a person (or animal). The nature of the interaction with animal and other toy robots may also be problematical and based on the deception that the robot is real. Another area which gives rise to serious concerns is the proliferation of sensors, the monitoring of the occupant and the collection of personal data in smart home applications. This raises a range of privacy management issues, as well as the rights of elderly people to make choices and take risks. In summary, assistive robots have considerable potential to support disabled and elderly people, but this requires them to be used sensitively and appropriately.

In particular, they should be seen as being complementary rather than as a replacement for personal assistance. This issue and concerns about loss of contact with real people emerged vividly in the brief discussion of user acceptance. It was noted that the approaches to modelling user acceptance consider either positive or negative factors, but not both. There is a need for further research in a number of different areas, including:

- User involvement and requirements
- User acceptance and use of assistive robots
- Development of the underlying technologies; development of applications
- Privacy management
- Outcome evaluation

User involvement is essential to determine what applications are likely to be of interest to disabled people and to determine their requirements, while recognizing that each user of assistive robotics is an individual with their own specific needs and preferences. User involvement in all stages of the process of the design, development and implementation of assistive robots is crucial in ensuring that users are in control of the ways in which robots are used to support them.

There may be a need for the development of new methodologies for user involvement, particularly for determining the wishes of elderly people with dementia. There is a need for the investigation of both the factors which affect user acceptance and attitudes to robots and improved models. Continuing progress is being made in both the underlying technologies and their applications, to the extent that any state of the art overview is very soon out of date.

However, there remains a need for further work in many areas, including stable walking mechanisms, control architectures, artificial intelligence, speech recognition, brain computer and other types of interfaces, and shared control. There is also a need for both the development of robotic applications in new areas and the development of existing application areas, such as robotic wheelchairs, beyond the prototype stage, in order to give potential users a wider range of choices. Research into privacy management should have at least two main components: the investigation of users' concerns and the trade-offs that they are and are not willing to make; and the development of improved privacy management systems.

Conclusion

There are many needs and many good ideas in the world, but few become commercially successful products. Various sources estimate that it takes anywhere from 25 to 400 ideas to lead to one successful product. Research and development is challenging – it is often expensive, can take years to complete, and there is always the risk that the product does not "work" as intended or sell well. These challenges can be magnified in the AT industry. When compared to other technology markets, the AT market is small and specialized. While there are millions of people with disabilities, that is a small fraction of the general population. In addition, since people with different types of disabilities have unique needs, the market for each group is small and specialized.

Predicting the future in any domain is difficult, and when technology is involved, predictions can often be far off from eventual outcomes. But the rate of technological innovation, coupled with the rate of adoption of those innovations by consumers, for example cell phones, has been world changing. The incorporation of sophisticated computational and sensor technologies in consumer devices, combined with the adaptable nature of software (or apps) that drive these devices, strongly suggests a future that holds tremendous opportunity for enhancing the lives of those with sensory, cognitive, and physical disabilities.

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