Smart Assistive Technology for People with Vision Impairment

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Introduction

Assistive Technologies have played a big part in maintaining the independence of people with disabilities for decades. Occupational Therapists have played a major role in recommending both adaptations to the home environment, and specific devices and systems that can help to overcome functional, intellectual, mobility or sensory issues that limit their ability to live independently. These disability or issues can appear at any time during someone’s life and, if they occur following the trauma of a motor vehicle accident, for example, their impact can be life changing. However, as more people live to become “very old”, they tend to suffer from more long term conditions, such as osteoarthritis, hypertension, and Type 2 diabetes. These conditions, coupled with other age-related changes to hearing and sight, can result in disabilities that can significantly decrease Quality of Life unless addressed with a combination of Assisted Living solutions. The challenge is rapidly becoming one of helping to support the many thousands of people with severe disabilities while also finding innovative approaches to supporting the millions of people who may have one or several disabilities for the final years of their lives.

What is Smart Assistive Technology?

Assistive Technologies (AT) support the self-care and management agenda, and also the many family carers who provide unpaid help to their loved ones. Traditionally, they consisted of 3 groups:

1. **Fixed systems** – primarily adaptations to the home such as ramps, lifts, grab-rails and level-access showers that help people with mobility problems to carry on living in their own homes more easily, and more safely;
2. **Portable devices** – these include walking sticks and smaller items that can be carried on the person or in a bag to be used anywhere, or placed in specific locations around the home; and
3. **Electronic systems** – including environmental controllers, and complex electro-mechanical equipment designed to help with transfers, feeding, or communication.
A fourth group has been added during the past 20 years to reflect the role of connected technologies in enabling people to live independently, but supported remotely by a network of carers or other support organisations. Telecare and Telehealth services are examples of connected technology applications. But if appropriate portable devices such as electronic reminders are included in service propositions, then an Enhanced Telehealthcare service is created which can be more successful in managing risks and addressing some of the issues which threaten the independence of service users. Four AT groups are shown in Figure 1 at the corners of a rectangle of support which, when all are available for consideration, leads to a full, integrated technology support service capable of addressing the needs of all people, and of empowering them to live life to the full.

Both electronic AT and connected AT are examples of Smart Assistive Technology, but it is their convergence which is driving a new agenda of support. In particular, it is the emergence of handheld portable computing devices (i.e. smartphones and tablets) which has created a communication platform which can be used both for normal communication purposes (such as phone calls and text messaging) and for a spectrum of care and support applications based both on the device’s internal resources, shown in Table 1, and on their links and interactions with peripheral devices such as wristbands, headsets and other physiological sensors. In all cases, the technology application requires the use of a software program called an “app”. An app can be downloaded from the appropriate “App Store”, and installed by the end-user in a process that is as simple as buying a digital version of a pop song for use on a MP3 player or an iPod – and needs no IT specialist. This demystifies the technology and makes it both acceptable and desirable as an alternative to a High Street store. It could be highly disruptive to the care and support industry in exactly the same way as
downloaded music and films have been to record and video shop, but could also create opportunities for new Digital Health and Care Support organisations who could advise on downloads and manage their use, maintenance and upgrades. Many new apps are being created which are viable alternatives to traditional but expensive items of hardware.

Table 1: Features and Components of a Modern SmartPhone or Linked Tablet Device

<table>
<thead>
<tr>
<th>Features</th>
<th>Sensors, actuators and connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powerful processors</td>
<td>Microphone</td>
</tr>
<tr>
<td>Large touch-screen colour display</td>
<td>High quality audio</td>
</tr>
<tr>
<td>Large memory and storage capacity</td>
<td>Accelerometers</td>
</tr>
<tr>
<td>Telephone and text-messaging</td>
<td>GPS and GSM location</td>
</tr>
<tr>
<td>Versatile apps</td>
<td>Magnetometer</td>
</tr>
<tr>
<td>In-App notifications and messaging</td>
<td>Temperature</td>
</tr>
<tr>
<td>Familiar interface options</td>
<td>Camera(s)</td>
</tr>
<tr>
<td>Lightweight and always available</td>
<td>Vibration unit</td>
</tr>
<tr>
<td>Battery life improving</td>
<td>Bluetooth and Wi-Fi for connectivity</td>
</tr>
<tr>
<td>Contactless and touch ID</td>
<td>NFC and proximity sensor</td>
</tr>
</tbody>
</table>

What is Vision Impairment?

Vision Impairment (VI) is the consequence of a functional loss of vision rather than the eye disorder itself. It is not necessary therefore to define VI in terms of the catalogue of permanent conditions or chronic diseases that result in a loss of vision. However, the impact may be described through 3 terms:

- **Low Vision**: a person can see, but not well, and full vision can’t be enabled by surgery.
- **Legally Blind**: someone lacking visual perception due to physiological or neurological factors so that they can’t see well or have minimal vision e.g. they can’t see at 6 metres what others can see at 60 m.
- **Totally Blind**: someone who can’t see at all (less than 20/200 vision in their better eye), and who must therefore depend on their other senses.

The World Health Organisation believes that there are 285 million visually impaired people in the world, including 39 million who are blind. 90% of them live in “low income” countries while a similar percentage are impaired as a result of having a
chronic condition such as diabetes. They are 3 x more likely to be unemployed or be involved in a motor vehicle accident, or to suffer from anxiety or anxiety disorder. 85% are aged 50+ years, and this percentage will grow rapidly as life expectancy increases. It is not surprising that people with VI are twice as likely to suffer a fall compared with fully sighted people.

Table 2 lists seven common causes of Low Vision some of which affect acuity, while others affect the visual field and ability to process colours. Most make vision especially difficult when the available level of lighting is poor. The exact number of people who fall into each category is difficult to estimate, especially as some will suffer from more than one cause. It may be apparent that technology can be applied in different ways to support the needs of people who are fully blind compared with those who have some remaining vision.

Table 2: The Major Causes of Vision Impairment

<table>
<thead>
<tr>
<th>Cause of VI</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Central Vision</td>
<td>makes it difficult to read, recognize faces and distinguish distant detail</td>
</tr>
<tr>
<td>Loss of Peripheral Vision</td>
<td>loss of peripheral vision (“tunnel vision”) can affect mobility and reading.</td>
</tr>
<tr>
<td>Blurred Vision</td>
<td>both near &amp; far vision is out of focus, even with the best possible correction</td>
</tr>
<tr>
<td>Generalized Haze</td>
<td>a sensation of a film that can extend over the entire viewing field.</td>
</tr>
<tr>
<td>Extreme Sensitivity to Light</td>
<td>ordinary light levels overwhelm the visual system, producing a washed-out image and/or a glare and pain.</td>
</tr>
<tr>
<td>Night Blindness</td>
<td>inability to see outside at night under moonlight, nor in dimly lighted interiors</td>
</tr>
<tr>
<td>Colour Blindness</td>
<td>decreased ability to see colour, or colour differences, with normal lighting conditions</td>
</tr>
</tbody>
</table>

Mobile Phones for People Who Are Blind or Visually Impaired

The importance of communication may be apparent for everyone from the young who may be venturing out alone for the first time in their lives, through to older people who may be anxious about suffering an accident, feeling unwell or becoming lost when out and about. Mobile phones have transformed our lives and there are relatively few people who don’t carry one (and sometimes more) with them at all times. The exceptions include some older people who claim that they are unable to use them (but who are still happy to use a landline telephone), people who have a disability that makes using a small phone difficult, and others who simply don’t want to be connected at all times, irrespective of the benefits in emergencies. Manufacturers have recognised the problem and introduced simpler phones with big buttons and displays
which can be useful both for people with VI and for those with dexterity issues. Table 3 shows a range of such phones, all characterised by having few of the features and in-built sensors shown in Table 1.

Table 3: A Range of Simple to Use Mobile Phones that May Be Suitable for People with VI and Others

<table>
<thead>
<tr>
<th>Model</th>
<th>EasySMX vkworld</th>
<th>Lifeline 925</th>
<th>Denver GSP 110</th>
<th>Doro 580 Secure</th>
<th>Binatone AN001</th>
<th>Ownfone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Guide price</strong></td>
<td>£30</td>
<td>£20</td>
<td>£32</td>
<td>£130</td>
<td>£20</td>
<td>£50</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td>Large buttons, Red SOS, Hands-free mode, Radio, Camera, Flashlight</td>
<td>Large buttons, SOS, Touch-dial, 10 hours talk-time, 10 day standby battery</td>
<td>Large buttons, SOS, Bluetooth, Calculator, Calendar, Speed dials, Alarms, Flashlight</td>
<td>One button control, 4 buttons, fast dial, SOS button, can send SMS alert, Works with hearing aid</td>
<td>Talking, large buttons, Hands-free speech, SOS button, Torch, Phonebook</td>
<td>Credit card size, Simple operation, Named personal contacts, Choice of colour</td>
</tr>
</tbody>
</table>

However, the benefits of genuine smartphones are their flexibility and their ability to provide functionality that goes considerably beyond the basis communications of the devices shown in Table 3. In particular, they can communicate with a range of peripheral devices, either through direct wired connections, or through wireless Bluetooth or Wi-Fi links. For most of the additional opportunities are based on their ability to run bespoke applications, or apps. There are hundreds of thousands of these apps already available for download, many available free of charge. They cover a wide range of subject areas, of which healthcare is one of the most popular. Many retired people, many of whom both fear technology and have vision impairment, are unable to use them effectively for a number of reasons, some of which are related to a lack of confidence and ability to read and follow instructions. Younger people, who include most of those who are fully blind, may appreciate the potential for the technology to support them in their daily lives, and may be enthusiastic in wanting to use smartphones or feature phones. However, their inability to see the display, and buttons, however big they might be, makes mainstream phones impossible for them to use.
Fortunately, a number of new mobile phones have been developed especially to benefit blind people. Though none yet use innovations such as Tactus Technology’s microfluidic technology (that allows real buttons to rise from the screen, with their location, size, shape, and firmness controlled by the current application on-screen). Nor do they yet use new frictionless glass developments that use ultrasound to enable users to effectively “feel” shapes or vibrations through their touchscreens. But some smartphones are commercially available as dedicated platforms on which specific apps can be launched, or with peripherals that enable them to perform functions such as document reading that could be very useful to blind people. Table 4 shows four of the leading examples of smartphones that may be particularly useful for use by people with limited or no vision. They have a number of apps pre-loaded, but others, such as Video Magnifier may be added as required.

**Table 4: Full Function Smartphones for People with Vision Impairment**

<table>
<thead>
<tr>
<th>Phone Name</th>
<th>Georgie</th>
<th>Blindshell</th>
<th>Samsung Galaxy Core Advance</th>
<th>Ray Nexus5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image</td>
<td><img src="image1" alt="Georgie" /></td>
<td><img src="image2" alt="Blindshell" /></td>
<td><img src="image3" alt="Samsung Galaxy Core Advance" /></td>
<td><img src="image4" alt="Ray Nexus5" /></td>
</tr>
<tr>
<td>Price</td>
<td>Apps from Free to £1.20 (phone extra)</td>
<td>€ 339 (including phone)</td>
<td>~£170 for ultrasonic cover, ~£100 for optical stand phone ~£200 extra</td>
<td>~$ 1000 for phone with Ray system preloaded</td>
</tr>
<tr>
<td>Features</td>
<td>Voice-assisted touch-screen for dialling numbers Apps to help with tasks such as catching a bus and reading printed text 3 different app bundles - travel, lifestyle and communication</td>
<td>Simple control using touch gestures Easy to learn (&lt; 1 hour) Book reader, colour indicator, magnifying glass, Bookshare library, and banknote recognition software</td>
<td>Help users navigate, sense environment and communicate Ultrasonic cover spot objects ahead; vibrates for warning Works with optical scan stand to read aloud anything put on its surface Identifies smart NFC labels &amp; speaks out identity of product</td>
<td>Touch-screen based inputs using finger gestures Homogeneous interfaces across system functions Single gesture access to many functions Vocal commands Speech recognition Remote support</td>
</tr>
</tbody>
</table>

**Improving Existing Vision**

Developments in “bionic” eye components have the potential for fully blind people to provide some form of vision for those who have specific conditions such as outer retinal degeneration. They have significant potential and various designs have been
approved for use across most of the developed world. However, they involve surgical interventions to insert devices within the eye; they will not be discussed further in this paper, which will focus on external devices and systems that can benefit people suffering from VI.

Night Vision Devices appeared as Image Intensifiers for military purposes following the Vietnam war, enabling soldiers and pilots to literally see in the dark. They were originally large, awkward machines that used lots of power, but modern Night Vision Monoculars, Bi-Oculars, Binoculars and Goggles are available commercially on various web stores and are able to amplify available ambient light levels in order to transform a very dark night time scene into a brighter picture. This can enable the user to recognise features and objects that would otherwise remain masked by darkness. Similar technology could be used by people with Visual Impairment to make the most of any vision that remains, much in the same way as a hearing aid might boost a nearly deaf person’s ability to hear sounds.

One leading example of a sight amplifier is the eSight Vision system which is being developed by Stephen Hicks and his group from the University of Oxford. They have produced a pair of glasses that can enable someone who has got very little sight to allow them to walk around unfamiliar places, to recognize obstacles, and to get a greater independence. They are constructed using transparent OLED displays, 2 small cameras, a gyroscope, a GPS unit, and a headphone. Data collected by the cameras can be processed and used in various ways including the use of brightness to show depth so that wearers can detect shapes including people and large objects. Machine learning can then be applied to enable the identification and classification of different shapes. This could be used to read signs and provide spoken directions.
Another example of image enhancement and processing comes from NuEyes, who use a combination of custom software and smart glasses, to restore some sight to people with serious vision loss. A camera on the front of the blacked-out glasses acts as eyes. Captured images are projected on the lenses. A speech-recognition feature lets wearers use voice commands to improve the image projected through the lenses to best remedy their particular condition. Earbuds let users listen to a text reader or other media via a Bluetooth-connected device. The device shown in Figure 3, which is already available at ~$6000, features variable magnification, voice activation and control over contrast and colour enhancement. Further features will be available in a Pro version due to be launched in late 2016.

Figure 3: The NuEyes System Launched in the USA

Correcting Visual Problems

One of the most common visual problems is Colour Vision Deficiency (CVD) sometimes referred to as colour-blindness. It can affect one in 12 men but far fewer women. Most people with deficient colour vision have inherited a gene from their mother, but some have developed the condition over their lifetime either as a result of a long term condition, such as diabetes, or as a result of ageing of a side effect of medication.

Most people with CVD can see things as clearly as other people but they unable to fully appreciate or differentiate between red, green or blue light. The most common form of colour is known as red/green colour deficit which means that they mix up all colours which have some red or green as part of the whole colour. For example, they will confuse a blue with a purple because they can’t ‘see’ the red element of the colour purple. CVD can lead to many problems in daily life ranging from clothes selection, to driving and food preparation. For example, they may not be able to tell whether a beef steak has been cooked to be well done or rage. Similarly, they may struggle to identify ripe bananas and tomatoes, and to differentiate between tomato ketchup and brown sauce.

These problems can increase safety concerns both regarding the appearance of people who are “off-colour” and in industries and the military where the correct identification
of colours is essential. Different coloured lights are used to control access and movement on the railways, in shipping lanes, aircraft flight controls, and at sea. People who have CVD are often denied employment in safety critical positions.

![Figure 4: Electronic Contact Lenses and EnChroma Cx Glasses for Correction of CVD](image)

Manufacturers of set-top-boxes can now include Eyeteq chipset as an option for customers with CVD. They use image processing algorithms to boost some colours in order to reduce the impact of the condition on the viewing experience. Electronic contact lenses that use 3D printing to produce multi-colour LEDs on contact lenses have found that they can improve and augment native vision. Similarly, EnChroma Cx glasses provide high colour contrast, producing an image in which the primary colours of red, blue, and green “pop” and are perceived correctly by the wearer allowing the effects of CVD to be overcome. These arrangements are shown in Figure 4.

Lazy eye, or amblyopia, is likely to affect between 2 and 3% of children, and can lead to long term vision loss. Current methods of treatment include eye patches and drops, which require a disciplined approach for success. The Amblyz electronic glasses, shown on the left in Figure 5 are programmed to automatically build the brain's reliance on the weaker eye by blocking out vision in either eye for programmable periods of time using LCD lenses. They are available in the USA for ~$450. On the other hand, many older people develop peripheral vision problems often as a result of glaucoma, concussion or stroke. They result in a reduced field of view, sometimes creating the sensation of seeing through a narrow tube, a condition commonly referred to as "tunnel vision" which can lead to problem seeing in dim light and a decreased ability to navigate while walking. A U.S. company called Gizmonyx, has developed electronic glasses, shown on the right in Figure 5, to help people with tunnel vision to see a wider field of view.
Figure 5: Amblyz (left) and Gizmonyx (right) Electronic glasses for Overcoming Lazy Eye & Tunnel Vision

Hardware for Visually Impaired People

The Braille tactile writing system was developed in 1824 by a Frenchman, Louis Braille, who lost his sight in a childhood accident. In 1829, he published detail of the system which was subsequently revised, and improved to include musical notation. Braille characters are small rectangular cells which contain bumps known as raised dots. The number of dots, and their spatial arrangement, are used to distinguish one character from another in its most basic form but can also be used to represent numbers, punctuation marks and some complete words in arrangements that are specific to each language.

Braille education has been an important element of support for blind and visually impaired children for a number of years for developing reading skills; it continues to be used today by specialist teachers who visit primary schools on a peripatetic basis. Braille literacy correlates well with higher employment rates. However, braille usage has been declining throughout the 21st century. This is, in part, in recognition of the fact that the vast majority of people with VI lose their sight later in life when out of full-time education (and when their ability to learn new skills has diminished often along with their tactile sensitivity). It is also because of the capabilities of technology to provide alternative ways of reading and writing as will be discussed below. It may be relevant to note that new designs for banknotes being consider by the Bank of England will not include Braille writing because of the potential of smart assistive technology to offer alternative and ubiquitous way of reading.
Table 5: Example of Hardware Used for Reading and Writing in Braille

<table>
<thead>
<tr>
<th>Device name</th>
<th>Braillenote Touch 32 Notetaker/Tablet</th>
<th>Brailliant BI 32 Braille Display</th>
<th>Embraill Desktop Embosser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture</td>
<td><img src="image.png" alt="Picture" /></td>
<td><img src="image.png" alt="Picture" /></td>
<td><img src="image.png" alt="Picture" /></td>
</tr>
<tr>
<td>Price</td>
<td>£3995</td>
<td>£1985</td>
<td>£1595</td>
</tr>
<tr>
<td>Description &amp; features</td>
<td>Combines benefits of traditional notetaker with power of tablet Uses TouchBraille – a natural way to type Allows easy access to apps and cloud storage</td>
<td>BI display is designed for extensive reading Offers full comfort and intuitive display navigation of HumanWare's signature thumb keys</td>
<td>Lightweight &amp; compact design Polymer platen creates smoothed rounded dots USB connection</td>
</tr>
</tbody>
</table>

It is traditionally written with embossed paper using the original slate and stylus method in which each dot is created from the back of the page, writing in mirror image, or it may be produced on a braille typewriter or Perkins Brailler. Unfortunately, braille letters produced in this way cannot effectively be erased and written over if an error is made. Braille-users can read computer screens and other electronic supports thanks to refreshable braille displays or they can type it on a braille writer, such as a portable braille note-taker, or on a computer that prints with a braille embosser once they are happy with what has been written. Table 5 shows a number of items of computerised hardware that are available to support braille users. It should be noted that they are very specialised and therefore quite expensive.

It is not surprising that text recognition software, and text to speech converter apps are rapidly removing the need to read braille. In the same way, voice recognition software has improved to such an extent that typing is becoming unnecessary; such techniques are proving to be life changing for people who have physical or dexterity problems. Figure 6 (left) shows a novel ring that sits on the finger and is capable of detecting and interpreting 12-point printed text as the user scans his or her finger across it. It reads aloud in real-time and offers a more natural way to read. Small vibrations alert the wearer to any deviation off the line. On the right of Figure 6 is a smart thimble (or finger glove). It offers a new literary experience by using the processing power of a smartphone to convert scanned text into impulses of Braille within the glove.
Figure 6: Novel Ways of Scanning Text and Presenting Words to the User

Other smart gloves fitted with ultrasonic sensors or cameras can help direct someone with VI towards small objects or to identify items on a shelf. The cameras can either read the labels directly and speak out the answers or it can check on a database to provide additional information including, for example, the ingredients, the amount of sugar contained and the number of calories. Such information might be especially useful to someone with an allergy to certain foodstuffs such as nuts.

Low Cost Smart Technology for Reading Support

There are dozens of free or low cost apps available to convert text to speech and are available on any smartphone or tablet device. The Aloud! Text to Speech app works with plain text, pdfs and HTML files. It also supports multiple languages and different reading speeds. TextAloud is a $4.99 app based on a more sophisticated PC version. It allows the user to listen to articles created from text copied to the clipboard in any app. The text can be deleted after it has been read out.

The KNFB app was developed through a collaboration between Kurzweil Technologies, the National Federation of the Blind, and Sensotec, a Belgian company. It costs $100 and is currently available only for iOS. It requires the user to simply point the phone camera at an object containing text, and enable the app to snap a picture. It automatically recognises the text in the image and starts reading it to the user whether the object is a book, an article, a label or a form. It includes additional features such as text editing and language translation. Figure 7 shows the app being used and a screenshot.
Figure 7: The K-NFB Reader App in Use

The smartphone also enables a number of low tech approaches to be employed by people with VI to use their network of contacts and volunteers to explore their surrounding or to answer questions relating to signs or notices that they might capture. The Be My Eyes app enables the user to request assistance by letting their contacts know what the problem whether it’s as simple as reading the “Best by” date on a food item or advice on how to find a particular location. The supporting helper can be connected by live video and can ask the person with VI to move their camera around to help them to find the required information. The VizWiz app offers a similar service but also supports sending the question to a IQ engine which automatically tries to recognise the content of the photo. It also allows the question and picture to be posted on Twitter.

Lifestyle Guidance

To encourage people with VI to be mobile and to explore and enjoy the environment both inside building and in the great outdoors, a number of systems and peripherals have been developed that help them to navigate and to avoid obstructions. GPS can provide basic information on location which is similar to that provided to motorist through their navigation systems. Errors of a few metres are likely, especially when walking along roads where there are high-rise buildings that can obscure the view of the satellites and indoors where there may be no GPS signal whatsoever. The role of cameras becomes paramount and the challenge is one of condensing information from
the visual field in such a way that it can be presented to the individual using alternative senses and in a format that allows simple interpretation.

The image on the left of Figure 8 is designed specifically for people who have some central vision but little peripheral sight; they are at risk of collision because they aren't aware of people or of objects approaching them from the side. The warning system is based on an estimate of the time to collision rather than on the actual proximity of obstacles, because an object is not a threat if someone is simply standing close to it. However, if it moves towards the wearer, or if the wearer is about to collide with something, it beeps.

**Figure 8: Systems to Provide Information based on Images Recorded by Video Cameras**

Other systems convert the image into a form that can be sensed by the body in an alternative way. The smart glasses, sold under the brand GiveVision in the middle of Figure 8 have been developed by UK company Vision Technologies using cameras, lasers and artificial intelligence software to deliver information to the wearer using speech. Once an object or street scene has been seen & recorded, subsequent encounters are announced through an earpiece. The wearer can also tag images of a person’s face by speaking their name out while filming, adding information & filing in a contacts list. The glasses can be taught to recognise anything from a shop entrance to bus stops, the number of an approaching bus & any empty seats. The system is sold on a lease basis at £50 to £80 per month.

The BrainPort V100 (Shown on the right in Figure 8) is a two-part system consisting of glasses with a video camera and a flat device, like a lollipop, that sits against the patient's tongue. The oral device receives electrical signals from the video camera and transmits these "images" to the patient's tongue via vibrations and tingling. Users are trained and learn with practice what these vibrations mean about the objects that the video camera is capturing. Blind patients can then learn information about their
surroundings such as the location, shape, size, position, and movement of objects. Reading of words in large print is also possible.

**Figure 9: New and Emerging Ways of Guiding People with VI**

A new approach from Israel (shown on the left and in the centre of Figure 9) uses musical scales to convey visual information. The system consists of a pair of glasses with an attached video camera which scans the scene in front of the user from left to right. This is linked to a pair of headphones that transmit sound into the wearer’s scalp rather than directly into their ears. The sounds are translated into “soundscapes” – short pieces of music played back through the headphones. The basic principle is that the higher a pixel is located vertically, the higher the note produced enabled the user to use their hand to move in the correct direction.

Meanwhile, Toyota is working on technology to help blind people navigate the world in an easy and intuitive way, building on its autonomous vehicle technologies. It is building a wearable device (shown on the right of Figure 9) that will have cameras capable of recognizing common indoor objects like doors, signs, and signs as well as people. Its actuators can point the user toward different destinations, or use speakers and vibration provide tactile and audio cues.

**Other Approaches to Exploring and Appreciating the Environment**

One of the greatest innovations of recent years has been the development of 3D printing using machines that reduce cost of producing single items by orders of magnitude. This allows complex and detailed shapes to be created using plastic materials that are lightweight, robust and weather-proof. The printing technique can be especially effective creating maps with contours which allow a person with VI to scan them with their fingers to identify outlines, changing is height and to plan routes. Braille can also be printed to identify individual rooms (as shown on the left of Figure 10). This can be extended (as in the centre of Figure 10) by including touch-sensitive elements so that when the user touches something on the map, a digitised voice describes what the object is and can provide directions to that spot if needed. The image on the right of Figure 10 is an example of fine art that a New York-based
company, 3Dphotoworks, has transformed from a 2D portrait to a 3D printed tactile representation is accessible to blind people.

Figure 10: Examples of 3D Printing of Maps, Guides and Fine Art that are Accessible to People with VI

The technique described above for creating tactile portraits can also be applied to drawings and photographs so that people with VI can appreciate shape and beauty, and then recognise people through their facial features. Facebook has already started to use Artificial Intelligence software to describe images that have been posted on its pages. It doesn’t actually “see” the picture, but it can compare objects with others in its vast database, and make an educated guess on what is being shown.

Alternatives to GPS for directions inside buildings and in underground areas is a major problem for people who are unable to see signs and landmarks. Talking signs have been available for a number of years but are not used in many places. The Harvard Audio-based Environment Simulator (AbES) uses audio signals to convey a map of an area that a blind person will then walk through. This engages the user to actively explore the virtual environment.

Currently, there is considerable interest in using beacons as fixed location points that can provide digital radio communication and become components in future Internet of Things arrangements. Bluetooth beacons are low cost options that can be used with existing smartphones. There are enhanced versions being trialled for use in otherwise difficult environments. The Sight Compass arrangement (shown on the left of Figure 11) is fairly localised and short range, and may be deployed at an individual building level to guide all people towards facilities so that they don’t need to ask for directions. Similar system would be ideal for people with VI. The London Underground system is being provided with iBeacons (see right of Figure 12) to help with location. Bluetooth tags can be attached to small items, such as spectacles, remote controllers and wallets, to enable them to be located using the Bluetooth facility and an app running on a smartphone. These are reducing the demand for other wireless systems to help locate lost items.
Other Practical Applications for Technology

Identifying objects has always been a challenge for people with VI. This has led to the use of individual coping methods such as putting a certain number of elastic bands around tins of soup, and a different number around tin of beans. There are simple devices such as Talking Tins that can be attached to food cans or other items usually stored in cupboards for many years. They require a description of the product to be recorded before being attached. Their use is limited by their size and by a price of over £5 per unit. This problem can be overcome by using coded labels together with a handheld code reader on which all the different descriptions are recorded. The most popular system currently in use is the RNIB PenFriend audio labeller which can be used with a wide range of items around your home and garden, at school or work or when out and about. short or long messages can be recorded for each label, making it perfect for labelling items such as music and film collections, frozen food and other items in the kitchen cupboards. The PenFriend washable laundry labels also allow the labelling of clothing and other washable items.
Whilst the personalisation of labels can be of great benefit to users, it remains something of a chore to prepare the labels and the messages, and to remove them from items once used and to recycle them. This also fails to appreciate the fact that all items sold in supermarkets (and by most retailers) are printed with a bar code. Whilst this was originally for the benefit of scanning products quickly at the checkout, the same process can be followed using dedicated talking barcode scanners such as the ID Mate Quest, sold in the UK by Sight and Sound. However, a smartphone’s camera can also be used to read a barcode and to link it with a database for identification. Many products today carry QR codes that provide a direct Internet link to a website that can provide further information. Therefore, the emergence of apps that can read and speak out labels are transforming the world of product identification. They also provide opportunities to find out more about products including similar products, such as wines, which may be distinguished by taste and where buyers seek information on opinions, vintage and type through apps such as Hello Vino, Dyno, and Cor.kz.

Unfortunately, there are different types of bar-codes in use in different countries, which makes universal apps something of a problem for the time-being. However, the food industry has moved beyond simple identification and apps such as Goodguide and fooducate.com (see Figure 12) provide not only identification but also composition, calorific content and support for reaching goals in achieving a balanced diet. In the same way, colour identification is important to match clothing and to choose the best food. It can be achieved using dedicate hardware, such as the Colour Identifier, or by using one of a number of apps including the 3 examples shown in Figure 14.

Figure 13: Hardware and Apps Examples of Systems to Identify and Speak Out the Names of Colours

Similar hardware versus software options exist in other areas of relevance including the identification of banknotes and in the management of long term conditions and health. Figure 14 shows the iBill US dollar reader (left) alongside several approaches that use the smartphone camera to take a picture of a note, compare it with a database and then speak the value. The LookTel Money Reader app (extreme right in Figure 15)
works for 21 different currencies including Sterling, the Euro and Australian, Canadian and US Dollars. The Euro is perhaps the most difficult currency to deal with because each country that uses it is allowed to produce their own national versions, all of which must be acceptable across the Euro region. This makes the Euro a likely target for counterfeiters; apps such as the EuroBiljet can help identify fake notes.

![Figure 14: Methods of Identifying and Speaking Values of Currency Notes](image)

In the same way, apps can be used to speak the time. There are literally dozens of free (or low cost) apps available for both Apple and Android devices. Some examples are shown in Figure 15. Others offer alarm facilities, count-down timers and various programmable reminders. They can also be used to provide chimes on the hour or every 15 minutes. It remains to be seen whether these methods will be as popular as the large number of speaking watches that are available.

![Figure 15: Example of Speaking Clock Apps for iPhones and for Android Smartphones](image)

Watches are more than devices for telling the time. Both men and women have over the years considered them to be appropriate items of jewellery that can be chosen to reflect their lifestyle and fit in with their clothing dependent also on occasion. It is therefore not unusual for people to own several watches and for some designs to be reserved for special occasions. There are some examples of non-speaking watches that are suitable for people with VI. The Dot watch shown on the left of Figure 16 has a Braille reader on its face and can connect to a smartphone via Bluetooth for programming. It works as a regular watch that tells the time, provides alarm functions and navigation information when out and about. Its main application is as an eBook.
reader that is easy to carry and accessible, and syncs wirelessly to download books to memory. The Korean developers hope that the device will also be able to display text messages and notifications, perhaps from public information broadcasts.

The device shown on the right of Figure 16 is the £200 Eone Bradley Canvas Blue watch. Powered by Swiss quartz movement, this watch has a ball bearing riding the circumference of the watch that shows the hour, and one on the face that points to the minute.

![Figure 16: The Non-Speaking Dot Watch and Eone Bradley Watch for People with VI](image)

**Health, Safety and Security Issues for People with Visual Impairment**

About half of all adults in developed countries live with one or more chronic health conditions such as heart disease, stroke, cancer, type 2 diabetes, obesity, and arthritis. One of four adults had two or more chronic health conditions which can be managed through medication, lifestyle changes, and good diet, but they cannot be cured. The monitoring of vital signs has become an important part of helping people to become experts in managing their own conditions. This can include using a telehealth service that provides remote monitoring, but long term benefits can be achieved by enabling a patient to take their own readings and adjusting their behaviour accordingly. This requires them to use their own peripheral devices which presented a problem to people who had VI. Fortunately, a new generation of these sensor devices is available; they can both communicate wirelessly with Bluetooth enabled devices, such as smartphones, and speak the results. Figure 17 shows talking devices that measure body mass, blood pressure, blood glucose level, temperature, and pulse and saturation levels of oxygen in the blood.
People who have VI can be victims of common domestic accidents including falls, fires, floods and medication mismanagement. Telecare systems have evolved from social alarms to include a range of smart sensors that can automatically detect emergency situations and issue a coded alarm that is received by a dispersed telephone unit. This device, such as the Reach unit shown on the left of Figure 18, acts as a receiving hub for virtually any number of smart devices of the type also shown in this diagram. They are selected according to assessed needs and to managed the perceived risks to independent living. People with VI are at increased risk of some types of accident, especially those that are associated with trips, cooking hazards and managing polypharmacy.

Many new kitchen appliances are designed to be more inclusive but with features that support greater levels of safety. These include toasters that have glass sides; they allow normally sighted people to watch their bread turn brown enabling them to intervene before they become burnt, but are also safer for use by people with VI as the glass sides will not become so hot that they could burn fingers if they came in contact with them. Similarly, single touch and single cup water boilers are useful to people with limited dexterity (which includes many older people) but are also ideally suited to those who may risk overfilling their cups and scalding through an inability to see how much boiling water has been produced. Other kitchen appliances, such as deep fat fryers, are equally useful to both fully and partially sighted people because they reduce the risk of chip pans boiling over and causing fires. Indeed, designers are paying more
attention to controls that are more intuitive on fridges, freezers, washing machines and tumble dryer resulting in more inclusive products that enhance safety. Cookers have yet to be improved much in this way, but can be protected by telecare safety devices that can automatically switch off the cooker if the temperature above the hob exceeds a programmed level for a relatively long time, or if it received a warning signal from a smoke detector or temperature extremes device located elsewhere in the home. Many people today use microwave oven rather than a stove for many cooking tasks. They can be protected with additional sensors but the “talking buttons” feature on some designs is ideal for people with limited vision, and prevents over- or under-cooking accidents. Figure 19 shows some kitchen products which are being supplied as part of telecare and AT service support by more progressive providers following assessment.

![Example of Kitchen Appliances](image)

**Figure 19: Examples of Kitchen Appliances that Are Relevant to the Safety of People with VI**

Unfortunately, people with VI who live independently in the community are more likely to become the victims of doorstep crime as well as burglary and assault; criminals may target them because of their difficulty in identifying the perpetrators and in providing police with useful descriptions of bogus callers, doorstep criminals, and other intruders, and of checking their identity cards. Once more, an appropriate use of telecare systems can play a vital role in providing support both by automatic detection of doors opening or of movement in rooms that should be unoccupied, and by using camera technologies.

Telecare monitoring centres may be used both as a form of teleconcierge to verify the identity of callers, and to collect images of those seeking to gain entry. External field cameras (usually used to capture images of birds and other forms of wild-life in the garden), and those used as peep-hole viewers, may be activated by movement, the knocking of the door, or the ringing of the door-bell; they can provide date and time-stamped images even in the absence of bright light. These images can be recorded or
transmitted directly to a monitoring centre, and used in subsequent prosecutions. Indoor cameras can be movement activated enabling both real-time video sequences to be monitored and for a remote viewer to speak to an individual (such as a monitoring centre call handler) to inform them that both their presence and actions have been recorded. Examples of peep-hole viewers and of linked camera systems are shown in Figure 20. These cameras and other sensing components are being used increasingly in Internet of Things arrangements.

**Figure 20: Field cameras, peep-hole viewers and linked internal cameras for improved security**

**Conclusions**

Technologies that can reduce the impact of having Visual Impairment have increased in number, complexity and features, largely through better design, innovations in sensor technology, and major improvements in information and communications technologies. Smart Assistive Technologies have developed both in addressing specific issues through bespoke hardware solutions, and by the proliferation of apps and peripherals that can be launched on the low-cost, high specification platforms that are available to everyone as smartphone and tablet devices.

It is likely that smart assistive technologies for people with VI will gradually reduce the importance of using Braille for reading and writing. Children who are today born blind will grow up with personal smartphone technologies and with tablet devices that will become their eyes on the world. They will enable text, numbers, music, signs and symbols to be read and relayed to them using a range of different interfaces designed to improve understanding and appreciation of the environment.

The level of support received will depend intimately on the advice that they receive, and on the local availability of services that can embrace the new technologies by providing individual assessment of needs and ambitions, and offering choice in technology applications that can help them achieve their own goals while removing the obstacles and issues that lie in their way. This will have a profound effect on the
services and on all people currently employed in the support of people with VI. Their training will need to be modified to enable them to refocus on smart assistive technology solutions and with more mainstream support options based on universal product design principles.

Progressive telecare service providers will recognise that they are well-positioned to extend their level of provision to include people with disabilities and to include relevant smart assistive devices in their inventories. Their staff will also need to be trained to understand sensory issues and the technology applications that they can offer to meet their needs.

**DURING THE AUTUMN (2016) AND SPRING (2017) I-CUHTEC WILL BE OFFERING TRAINING COURSES IN REGIONAL CENTRES OF ENGLAND AND WALES DEPENDING ON DEMAND. THESE WILL BE AIMED AT EXTENDING THE KNOWLEDGE AND SKILLS OF INDIVIDUALS IN THE TELECARE INDUSTRY IN ADDRESSING ISSUES ASSOCIATED WITH VISUAL IMPAIRMENT AND HEARING LOSS. THEY WILL ALSO AIM TO HELP TELECARE SERVICE PROVIDERS TO IMPROVE THEIR ASSESSMENTS OF PEOPLE WITH DISABILITIES, AND THE OPPORTUNITIES FOR HELPING THEM TO MAINTAIN THEIR INDEPENDENCE THROUGH THE USE OF TECHNOLOGIES. THE COURSES WILL ALSO BE OF RELEVANCE TO PROFESSIONALS IN SENSORY TEAMS WHO WANT TO UNDERSTAND MORE ABOUT TELECARE SERVICE SO THAT THEY CAN MAKE MORE APPROPRIATE REFERRALS.**