

NHS Digital Pathfinder

Mobile health for adults who have sight and/or hearing loss

A project in collaboration with West Yorkshire and Harrogate Partnerships

Introduction

When [West Yorkshire and Harrogate Health and Care Partnership](#) (WYHCP) won funding to deliver a local NHS Digital Pathfinder project, [Good Things Foundation](#) partnered with mHabitat to deliver a project in the Kirklees area. mHabitat has been working with WYHCP, local clinical commissioning groups, GPs and the voluntary sector to explore ways that digital technologies can support accessibility, and a better experience of healthcare, for people with sensory impairments.

Background

Since the 1st August 2016 all organisations that provide health and care are legally required to follow the Accessible Information Standard (section 250 of the Health and Social Care Act 2012). NHS Digital partnered with Good Things Foundation in 2017 and, as part of their [widening digital participation](#) work, launched a series of Digital Pathfinder projects across the country, aimed to support better access to care. You can get an overview of the different projects on Goods Things Foundation website [here](#).

Literature and Market Review

In the first quarter of the project, we undertook a rapid literature and market review of the digital technologies that could help people who are blind or sight loss, and deaf or hard of hearing, access health care.

We used the outputs from this review to inform a series of workshops with patients and GP surgery staff during May 2018, and to engage with GP practices, local charities and a wider community across the Kirklees area during the summer of 2018.

We will publish a final public report of our learning and findings in the the autumn of 2018. You will be able to access the report through the mHabitat open library which you can find [here](#).

This document draws on the literature and the market review to take a closer look at some of the challenges experienced when accessing healthcare and potential digital solutions, along with their benefits and limitations.

1. Challenges in accessing the healthcare system for people who have sight loss

In this section, we look at some of the challenges experienced by people who have sight loss when accessing healthcare. This includes features of the healthcare system which are not particularly accessible (such as appointment letters), poor communication with staff, personal factors (such as perceived loss of independence) and challenges in participating in some aspects of the care process (such as tracking visual symptoms).

This section has been adapted from **Cupples ME, Hart PM, Johnston A, Jackson AJ. Improving healthcare access for people with visual impairment and blindness. *BMJ* 2012;344:e542¹.**

People with sight loss may have great difficulty in accessing and negotiating healthcare services such as receiving written information in inaccessible formats, difficulties communicating with staff, staff failing to respect people's ability to participate in their own care, and challenges getting to and around healthcare facilities. They may also encounter problems trying to identify/diagnose a potential medical condition which relies heavily on visual signs (for example rash, mole, discolouration of skin or eyes) and during on-going treatment management (such as reading a drug information leaflet, or doing a blood glucose reading).

Some people, especially those who develop blindness or visual impairment in later life, may try to conceal it. For example, people with central vision loss later in life (such as macular degeneration) may still be able to move around confidently, especially in familiar surroundings, though they may have problems identifying faces or objects, or reading. As a result, health care professionals are not always aware that their patient has sight issues, and may misinterpret their behaviour (for example, not making eye contact or not following written instructions).

All of these factors can compromise an individual's ability to make informed choices about healthcare. A significant issue is missing appointments which can be especially problematic if a condition is time sensitive (for example, if not acted on quickly, it becomes irreversible) or it takes a long time for appointments to become available. Contributing factors include not being able to read printed information (appointment letter, leaflet), find the right phone number to make the appointment, and an individual's ability to find their way to the surgery or hospital and navigate the process of attendance. Other potential problems can occur when medication or therapy instructions come in a written format, packaging is hard to open or not distinctive, or certain forms of administration (measuring liquids, injecting oneself, administering eye drops), potentially exposing the patient to risks or loss of the treatment's (full) benefits.

In the above situations, not everyone can count on a support network to help them with each of these steps. Even if an individual does have access to support, they may choose not to

¹ <http://www.bmj.com/content/344/bmj.e542>

accept it as this can be seen as a loss of privacy and independence. People who experience slight loss suddenly or later in life may experience decreased self-confidence, making them less likely to ask for help and more likely to experience mental health difficulties.

Modern technologies intended to improve people's interaction with the healthcare system can potentially make things more difficult for people with visual impairments. For example, finding a button that opens a door is harder than just finding the door's handle, or signing in on the computer at the GP surgery presents more challenges than talking to a receptionist.

Receptionists may expect incoming patients to read signs or register attendance via a check in screen; the reception desk may not always be permanently staffed. A person with sight loss may find it hard to initiate a request for help for personal reasons (such as perceived loss of independence) or physical reasons (they don't know where reception staff are). Other issues include finding the right room within the building, communicating with staff (without seeing gestures or facial expressions, for example 'it's over there') and responding to visual cues summoning patients.

The actual consultation can also provoke anxieties due to a perceived lack of skills (such as acquired through visual awareness training) of the healthcare professionals. Patients report feeling ignored when a clinician appears to prefer addressing their sighted companion rather than themselves directly. Clinicians don't always describe what they are doing or going to do, including the various steps in procedures, or that they are leaving the room. They may be unsure how to guide an individual, either physically or verbally, to another area. Furthermore, appointments may take longer, in order that the clinician is able to explain verbally what other patients would receive as a letter or leaflet and ensure the patient has understood and made a record if necessary. Good communication empowers people and enhances their ability to manage their condition.

2. Mobile health solutions for sight loss

In this section, we summarise potential digital solutions to overcome some of the above mentioned challenges for people with sight loss. We start by introducing some general considerations about what is possible and desired in terms of mobile technology for people with sight loss. We then provide an overview of accessibility features available for smartphones, such as screen readers. Finally, we go into more detail exploring available tools to help with navigating the physical world, object and text recognition, writing and other options (including social interaction and crowdsourcing help).

2.1 General considerations

This section has been adapted from **Csapó Á, Wersényi G, Nagy H, Stockman T. A survey of assistive technologies and applications for blind users on mobile platforms: a review and foundation for research. JMUI 2015; 9(4): p 275–286².**

Visual input or feedback can be replaced by auditory and/or somatosensory senses. This is not a perfect solution and there can be issues with the quality. Additionally, this type of technology may be distract the wearer from, for example, environmental sounds. We know relatively little about which mode, audio or tactile, or a combination, is better suited to which

² <https://link.springer.com/article/10.1007/s12193-015-0182-7>

type of information. It may also depend on personal preference and personal ability to process different sensory information types.

Assistive technology, from conception and development through to testing and ongoing refinement, needs to be user centred; however, co-designing and prototyping apps and other digital tools with people with lived experience presents a challenge. Most quick early stage prototyping techniques are of a highly visual nature, such as drawing wireframes. Also, there is no common vocabulary for expressing the qualities of sounds and haptic interactions between non-specialist and specialist users. Finally, as mentioned before, it is important to allow personalisation of the experience based on personal skills and preferences (such as feedback as sound versus touch).

Most mobile devices include various sensors (such as microphone, camera, accelerometer, compass, GPS navigation) and can provide auditory and sensorimotor (vibrations) output. When data is available, devices can offer complex calculations through cloud-based resources and computing as well as crowd-sourced solutions. This means that smartphones and tablets can nowadays replace most of the old assistive technologies by installing an app, usually at a fraction of the price and requiring only minutes to set up. Android and Apple's iOS are the two dominant smartphone and tablet operating systems and both have built in accessibility features that can be activated while setting up a new phone or at any time (the latter may require sighted assistance).

Focus group research³ has suggested that smartphone users with sight loss favour the iPhone and are fairly late adopters. Blind users may have been more at a disadvantage until good accessibility features became standard, including screen readers and voice-activated commands. Apple may be particularly preferred due to its focus on a small family of similar devices, meaning the features are more consistent and easier to learn. Android, on the other hand, offers more flexibility which also means greater diversity which can be potentially harder to (re)learn.

2.2 Smartphone interaction

Alerts, including incoming messages and phone calls, can be assigned different sounds and audio caller ID can be used to identify calls. Voice commands allow hands-free and eyes-free control, including actions such as phoning a contact, composing an email, setting an alarm, or searching the internet for information or the nearest coffee shop. Android and iOS offer Google Now and Siri respectively as personal assistants to accomplish these tasks. Both are considered of similar quality.

A specific accessibility feature which can be useful for sight loss users is a screen reader, which adds spoken, audio and tactile cues to replace the visual display and gives feedback

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<https://lirias.kuleuven.be/bitstream/123456789/420480/2/Langdon%2Bet%2Bal2014Inclusive%2BDesigning.pdf#page=78>

on the user's actions. Both Android and iOS devices come with screen readers considered to be of similar quality⁴.

Most Android devices come preinstalled with some version of [TalkBack](#) (on older versions this was split into TalkBack, KickBack and SoundBack), a screen reader which provides options for spoken, audible (beeps, clicks etc), and vibration feedback to user interactions with the device, as well as reading text. However, the way to turn on accessibility mode, either for the first time (in the Settings menu) or using shortcuts to switch between modes, depends on the version of the operating system and may require sighted assistance.

VoiceOver is the iOS native screen reader, reading text on the screen and providing auditory feedback in response to user interactions. Once switched on via Settings, it can be switched on and off by pressing the home button three times. The user can control speed, pitch, verbosity and other parameters of the auditory feedback via the Settings menu. VoiceOver also works on Mac and users may prefer having such consistency across all their devices. Native accessibility features do not necessarily work for third party apps, either on Android or iOS. Both operating systems allow turning on accessibility while setting up the device, at least in theory omitting the need for sighted help.

Opinions on which is better, TalkBack versus VoiceOver, are divided - as mentioned before, Apple offers more consistency between their devices, but less flexibility in terms of modification⁵.

'I must admit I am a VoiceOver fan. While I like some of TalkBack's features - Especially the fact that it can automatically switch languages, I find its inaccuracy frustrating. When it can read through an app successfully, I find that I am provided with too much feedback, and I no longer know where I am or what I'm supposed to do next. VoiceOver doesn't bombard you with information, It's clear about where you are on the screen and is a lot more accurate.' (link to original source [here](#))

'TalkBack has a better tutorial... VoiceOver doesn't guide you through a tutorial, like TalkBack does' (link to original source [here](#))

'So unless you're a major geeky hacker, or an iPhone just isn't in your budget, I do believe that for now, as I write in June 2016, iOS is a more polished, reliable, efficient experience from an accessibility perspective. That said, those who say Android is unusable by a blind person are I think selling the platform short. If you have the opportunity to use an Android device for yourself, I highly encourage you to take that opportunity. If you're coming from iOS, give yourself some time. Some things are different, but that doesn't automatically make them inferior.' (link to original source [here](#))

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<https://lirias.kuleuven.be/bitstream/123456789/420480/2/Langdon%20Bet%20Bal2014Inclusive%20Designing.pdf#page=78>

⁵ <https://takesugar.wordpress.com/2014/07/22/accessibility-head-to-head-android-vs-apple/>

'In general though, Google's implementation of accessibility is great, but they have really just caught up in the last year or so. Prior to that, accessibility was there, but was more clunky than, for example, iOS. Google have pretty much caught up though and accessibility can be seen across Google apps. [...] I would say, if you're an Android or iOS fan, go for it. The times have never been so good for accessibility as they are now, and they are getting better all the time. Microsoft and Blackberry have some work to do, but I am hopeful they will get there.' (link to original source [here](#))

The following sections to 2.9 have been adapted from Csapó Á, Wersényi G, Nagy H, Stockman T. A survey of assistive technologies and applications for blind users on mobile platforms: a review and foundation for research. JMUI 2015; 9(4): p 275–286⁶ and Terven JR, Salas J, Raducanu B. New Opportunities for Computer Vision–Based Assistive Technology Systems for the visually impaired. Computer 2014: 47(4): p 52-58⁷.

Third party apps are available to extend or replace the built in accessibility features. [Classic Text to Speech Engine](#) includes a selection of male and female voices. [Vokul](#) is an app enabling voice-commands to control the smartphone (such as send and read messages), which also gives complete spoken feedback. The [Eyes-Free Shell](#) offers an alternative home screen specifically designed for people who do not look at the screen. [JustSpeak](#) offers a universal voice control solution for non-visual access to the Android operating system.

[BrailleBack](#) by Google is designed to be used together with TalkBack and lets you connect a supported refreshable braille display via Bluetooth. The braille display will present the mobile device's screen content and allow the user to navigate and interact with it. Text can be entered using the braille keyboard.

Research on nine common iPhone mHealth applications that upload data from blood pressure and blood sugar monitoring devices suggests that medical devices and mHealth applications can suffer from accessibility shortcomings ranging from improperly labeled buttons to confusing layouts that don't work well with VoiceOver or TalkBack services that 'read' information on the phone screen⁸.

⁶ <https://link.springer.com/article/10.1007/s12193-015-0182-7>

⁷ <http://ieeexplore.ieee.org/document/6576753/>

⁸ <http://www.washington.edu/news/2015/07/16/many-mobile-health-apps-neglect-needs-of-blind-users/>

2.3 Navigation

Generally, assistive technologies for obstacle navigation for people with visual impairment have been based on ultrasound, infrared, or laser sensors. Currently, even mobile devices have sufficient processing power to allow advanced scene-understanding algorithms to reconstruct the environment. However, some of these features such as GPS navigation and data turned on continuously can be quite draining on the battery. Also, the accuracy of the mobile device's inbuilt GPS can be low (although it can be augmented by an external GPS device), and is often unavailable indoors.

Native map apps (Google Maps and Apple Maps) in accessibility mode can be used to obtain basic turn by turn verbal instructions to reach a location, replacing a sat nav. Indeed the [Apple watch](#) work with a tapping function to tell you which way to go when Apple Maps is switched on.. Apps specifically aimed at sight loss people offer additional information, such as finding and describing intersections and crosswalks or finding bus stops and reading out arrival times.

BlindSquare offers spoken directions and describes the environment, including intersections. From a social networking perspective, BlindSquare is closely linked to FourSquare: it collects information about the user's environment from FourSquare, and allows users to check in to FourSquare by shaking the iPhone

GPS Lookaround speaks the name of the street, city, cross-street and points of interest upon shaking the phone

NowNav provides directions and information about the user's surroundings

Crosswatch helps users cross the street, using pattern recognition to analyse video feed of the street to find crosswalks with stripes (prompting an audible alert)

Intersection Explorer provides a spoken account of the layout of streets and intersections as the user drags her finger across a map

Ariadne GPS allows for the world to be explored by moving a finger around the map, signalling street crossings (vibration), announcing bus or train stops, and reading read street names and numbers

Talking buses finds nearby bus stops, arrival times and where to get off, all directly spoken to the user and designed specifically for people with sight loss (such as screen reader compatibility)

WalkyTalky uses GPS and provides real-time vibration feedback if the user isn't moving in the correct direction

Talking Location enables users to learn their approximate position through WiFi or mobile data signals by shaking the device. The app allows users to send SMS messages to friends with their location, allowing them to obtain help when needed.

Apps such as ‘**Straight Line Walk for Blind**’ and ‘**Walking Straight**’⁹ have been developed to facilitate straight-line walking using mostly the device’s magnetic sensor.

Navigating around objects and/or indoors (for example finding doorways, detecting stairs) can be done simply by detecting obstacles and their distance from the user, similar to using a cane. For example, **Virtual White Cane** combines a laser pointer and vibration to alert the user to an object’s proximity. Video Motion Alert (**VM Alert**) sounds an audible alert when detecting motion as seen through the camera and can optionally save images of the motion. More advanced object detection systems include the use of visual input to generate occupancy maps and give auditory and/or haptic feedback, often requiring additional equipment, for example **Virtual Acoustic**, the **Electron-Neural Vision System**, the **Tactile Vision System**, **Tyflos**, **KinDetect**, and the **Vibratory Belt**. More comprehensive applications combine some of the actions above with more environmental cues such as light, colour and text.

Fifth Sense Project¹⁰ aims to find a safe walking surface, detect collision hazards, and generally provide a rich set of orientation capabilities. It leverages surrounding cues, such as text signs and features, to provide the user with enough information to know current position and how to get to a desired destination, as well as to infer common locations such as a kiosk, concierge desk, elevator lobby, or water fountain

The vOICe maps live camera views to soundscapes¹¹, providing sight loss people with an augmented reality based navigation support. The app includes a talking color identifier, talking compass, talking face detector and a talking GPS locator. The vOICe uses pitch for height and loudness for brightness in one-second left to right scans of any view: a rising bright line sounds as a rising tone, a bright spot as a beep, a bright filled rectangle as a noise burst, or a vertical grid as a rhythm.

2.4 Object (and colour) recognition

Through either video or photo input, apps can recognise objects and colours and name or describe them to the user. This may depend on mobile data being available if there is a need to compare to a general database of objects.

The **oMoby** app searches the Internet based on photos taken with the device’s camera and returns a list of search results

LookTel Recognizer app allows users to build a library of pictures of common objects with their own custom descriptions, which the device will then recognize and describe instantly

LookTel Money Reader recognizes currency and speaks the denomination, enabling users to quickly and easily identify and count bills in real-time

⁹ https://smartech.gatech.edu/bitstream/handle/1853/51516/03_S1-2_Paneels.pdf

¹⁰ <http://people.csail.mit.edu/teller/misc/bocelli.html>

¹¹ <https://www.seeingwithsound.com/>

TapTapSee speak the identification of any photo taken by double tapping the screen.

Talking Goggles speaks out the object (or text) in front of the camera.

Aipoly recognizes objects and colours from live video, offering a constant description.

Color ID, **Color Picker** and **Seenesthesis** offer color identification.

ShelfScanner recognizes supermarket objects that the user has put in a shopping list on the smartphone. As the user moves the camera through the aisles, the application detects the objects (using an internal database) and compares them with the ones on the list, notifying the user when it finds a match.

A different approach is possible through crowdsourced solutions, that is by connecting an individual to a human operator. **VizWiz** is an application that records a question after taking a picture of any object. The query can be sent to a human volunteer or an image recognition platform or can be emailed or shared on Twitter. Other examples of crowdsourced apps include **Be My Eyes**, **CrowdViz** and **BeSpecular**, which can be used for other purposes as well and are discussed in section 2.9.

2.5 Optical character recognition (OCR)

OCR includes reading printed text, numbers, barcodes and QR codes, and is a very common application. However, in order to be most useful for sight loss users, the output needs to be read aloud, and the input needs to be robust (since the user may not see what they are putting in the centre of the camera). An example would be **Trinetra** which uses product barcodes to help users recognise supermarket objects, and includes an algorithm which helps locate the barcode by giving left or right indications until the user succeeds in focusing the camera on the code.

An app for **Automatic Bus Line Number Localization and Recognition** enables users to recognise bus numbers by combining geometric computer vision with machine learning to achieve robustness against reflections, shadows, and partial occlusions.

Instant OCR scans a live image and reads aloud in real-time.

KNFB reader takes a picture of printed text and reads it aloud. It can read virtually any type of printed text in different sizes and layouts. Documents can also be saved to read at a later time.

2.6 Writing

As mentioned in section 2.2, **BrailleBack** allows text to be entered via the braille keyboard of a refreshable braille display connected to the mobile device via Bluetooth. **BrailleType** turns the mobile device itself into a braille keyboard. Using single finger presses and swipes, the user forms the traditional braille characters on a 2 by 3 dot matrix, and is given verbal feedback. This simple direct graphical representation and absence of multi-touch gestures is a good introduction to touch screen device typing. Alternative methods, while faster, may also be harder and more error prone¹². **BrailleTouch**¹³ offers faster typing by using up to six fingers at the same time (three on either side of the touch screen) to create the braille character (with audio feedback).

Text entry without using Braille is also possible in accessibility mode (for example VoiceOver reads out the character the user is touching on the virtual keyboard) or using specific apps, such as **No Look Notes** which tries to enable faster and more accurate typing¹⁴.

Arguably the fastest way to produce text is to use speech to text applications. In addition to the mobile device's built in functionality (such as Google Keyboard), there are specific apps such as **Dragon Dictation**, **Speechnotes** and **Speech To Text**.

2.7 Other

iCARE Social Interaction aims to empower sight loss individuals during social encounters by providing visual information about those around them. The prototype system uses a camera embedded in eyeglasses that communicates with a smartphone. Employing computer vision algorithms, iCARE detects the other person's position and transmits this information to the user through a vibrating belt. The system can also detect six basic emotions — happiness, sadness, surprise, anger, fear, and disgust — as well as a neutral emotional state. It then provides this information to the user through a glove with 14 small vibratory motors in the fingers.

VORail has been described as Facebook for audio-users; it is a social network app uniting a large community of users with sight loss.

For users with some remaining vision, filters and virtual magnifying glasses, such as **Magnify**, may be useful.

Awareness is an app that plays environmental sounds through headphones so the user can stay aware of their surrounding even when listening to ,for example, another app reading out directions.

Light Detector transforms any natural or artificial light source into sound (pitch depends on light intensity). This could be useful for checking if a device monitor or even smaller indicator LED of an electrical appliance is on.

¹² https://link.springer.com/content/pdf/10.1007%2F978-3-642-23774-4_10.pdf

¹³ https://link.springer.com/chapter/10.1007/978-3-642-21666-4_3

¹⁴ <https://www.cc.gatech.edu/~keith/pubs/perv2010-nolooknotes.pdf>

As set out earlier, crowdsourced apps that bring a user in contact with a sighted volunteer can have a wide variety of uses, including reading a label, finding an object or help with navigation. **Be My Eyes** and **CrowdViz** establish a live audio-video connection with a sighted volunteer whereas **BeSpecular** is based on pictures.

Read for the Blind is a community-powered app that allows users to create audio books for the blind, by reading books or short articles from magazines, newspapers or interesting websites.

Guard My Angel will automatically notify selected friends or family of your last known location (by SMS, email or facebook) when the user either hits the SOS button or a pre-set timer expires after activating the "Watch Over Me" button.

3. Challenges in accessing the healthcare system for people who are deaf or hard of hearing

In this section, we turn to challenges experienced by people who are deaf or hard of hearing. Evidence suggests that significant proportion of deaf people find it hard to interact with healthcare services, as a result of factors such as low health literacy and/or communication challenges. Examples of the latter are telephone only NHS services, limited availability of BSL interpreters, and difficulty in describing symptoms.

This section has been adapted from *Kuenburg A, Fellingner P, Fellingner J. Health Care Access Among Deaf People. Journal of Deaf Studies and Deaf Education 2016; 21(1), p1–10*¹⁵.

The 2015 'GP Patient Survey' reported 44% of deaf patients found the last contact with their GP or health centre difficult - compared with 17% from a general population. Getting in contact with emergency services is a particular challenge. As a result, deaf patients tend to use healthcare services less often, similar to language-minority groups.

Making appointments (or asking a quick question) is still not always possible via email or another text messaging service, as many NHS services are only available via telephone. Miscommunication often occurs between patients and their health care providers, contributing to a feeling of mistrust with associated negative influence on diagnosis as well as therapy. Health care providers are often unaware of the culture and health needs of deaf people, leading to assumptions and misconceptions.

Researchers found deaf patients may get anxious and frustrated in medical contexts, because they cannot use spoken language to interpret their symptoms and feelings; as a result, nurses or physicians tend to make diagnoses based on obvious symptoms, which can lead to medical errors.

¹⁵ <https://academic.oup.com/jdsde/article/21/1/1/2404217>

BSL is usually the native language of prelingually deaf adults, but may not be (well) known to people who lost their hearing late in life. Written English or lip reading is not a good substitute for BSL, as this is a different language the patient should not be expected to be fluent in. Only 7% of BSL users reported they would be happy to communicate with doctors via speech rather than sign language. In addition to being a language in its own right, BSL does not offer translations for all medical terms.

The use of a BSL interpreter is not straightforward. By law, the healthcare provider needs to find and pay the interpreter, but this depends on the patient making clear they want one and it may be difficult to find one on short notice. Another factor is the potential embarrassment of discussing sensitive medical conditions in the presence of an interpreter, and the perceived lack of independence.

Short message service (SMS) and email are often preferred by deaf people because they are convenient, support a high level of privacy, and enable users to express their emotion and reaction in a message using emoticons.

Health literacy among deaf people is low, possibly due to the fact that they have greater difficulty accessing health information than hearing people. They do not have access to incidentally occurring information about health issues, for example on the radio or TV, and there is a general lack of health information and education materials provided in sign language. For example, in US studies, over 60% of deaf adults could not list any stroke symptoms (compared to 30% of hearing adults), and only 49% of deaf adults could list chest pain/pressure as a heart attack symptom (compared to 90% of the general population). As a result, deaf people may be slower to diagnose a problem and less able to comply with procedures or therapies they do not understand.

4. Mobile health solutions for people who are deaf or hard of hearing

In this section, we explore solutions to the above mentioned challenges. Note that there are no inbuilt accessibility features on smartphones that are designed for a visual experience without audio feedback. We start then by introducing some general considerations about what is possible and desired in terms of mobile technology for people who are deaf or hard of hearing. Finally, we give an overview of existing tools, which mainly focus on facilitating communication, such as BSL translation and speech to text conversion, and alerting users to sounds.

4.1 General considerations

Auditory input or feedback can be replaced by visual and/or somatosensory senses. Again, the choice of mode may depend on personal preference and personal ability to process information.

Focus group research¹⁶ has suggested that deaf users, compared to blind users, show a wider variability in smartphone choice and have adopted them more quickly. The quick adoption by hearing impaired users may be due to the advantage of text messaging over 'wired' phones which mainly rely on voice communication.

Hearing impaired users may experience fewer disadvantages trying to use mobile devices compared to blind users, since most features are vision-based. Manuals and tutorials usually come as written text or increasingly often videos, both manufacturer and user made. Video captions are becoming more common as they also cater for non English speaking users and users without headphones (such as listening in a public or loud space).

When judging the usefulness of apps or features, it is important to keep in mind that either BSL or written English may be preferred by different users. For example BSL may be preferred when it is a user's native language, but not when the user has lost their hearing later in life and is more (or only) fluent in English.

For BSL output to be most useful, videos need to be of sufficient quality (large resolution, sufficient contrast between interpreter and background). For speech to text apps to work optimally, they need to be able to work in conditions of poor signal to noise ratio, such as loud background noises, and be able to 'understand' the accent of the speaker.

4.2 SmartPhone interaction

Deaf users show a quicker adoption of smartphones and associated accessibility features and apps. This may be due to the advantage of text and/or video messaging over 'wired' phones which mainly rely on voice communication. As set out in Section 2.1, most mobile device features are vision based and most of the interactions do not require audio feedback, with the notable exception of making traditional phone calls. Alerts can be set to use visual stimuli (for example flashing LED) or vibrations, with the option to assign different cadences

¹⁶

<https://irias.kuleuven.be/bitstream/123456789/420480/2/Langdon%20Bet%20Bal2014Inclusive%20Designing.pdf#page=78>

or rhythms to different types of communications such as text messages, emails or phone calls.

The small size of smartphone screens and the quality (and cost) of video streaming can be barriers to the use of BSL. High resolution front facing cameras currently come as standard, which means only older devices may present a problem when using video calling.

4.3 Communication and translation

Individuals can use a variety of standard text or video communication apps. **Glide** is a favourite video messaging app among BSL users¹⁷, which includes group chats and uploading videos to social media.

Arguably the biggest challenge is communication between deaf users and hearing people, especially in the setting of the healthcare system. Depending on the user, they may prefer to communicate via text or BSL. Several apps offer the services of a qualified (human) translator to communicate verbally with hearing people over the phone, such as when making an appointment.

NGTS (Next Generation Text Service) allows users to type text to a relay assistant who will speak your words to the person being called, and the relay assistant will type their reply so the user can read it on their display

Interpreter Now, in addition to offering NGTS's above type and read option, also offers an instant video-relay app specifically designed for BSL users, which allows them to communicate with others via a qualified BSL interpreter

Z4 Mobile also offers a BSL interpreter service to verbally translates BSL to a hearing caller, in addition to point to point video-calling between BSL users.

Non-emergency communication, for example in waiting rooms, can be improved by apps such as **Signly**¹⁸. After scanning a barcode with a mobile device, Signly adds a pre-recorded video of information given by a BSL interpreter to the screen.

In real time, there is a wide variety of apps that can be used to convert speech to text, including the popular **Dragon Dictation**, which can also 'speak' written text out loud. However, there are also apps specifically designed for deaf users offering features such as describing sounds and assigning speech to different individuals in a group conversation. **Scribe4Me** offers a transcription of the last 30 seconds of sound to the user as a text message. Transcriptions include dialog and descriptions of environmental sounds¹⁹.

¹⁷ <https://deafunity.org/article-interview/top-10-apps-for-deaf-people/>

¹⁸ <https://signly.co/>

¹⁹

https://s3.amazonaws.com/academia.edu.documents/30761530/scribe4me.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1512579521&Signature=mrhUYNsp1Do2emD1NiABqpx%2F9V8%3D&response-content-disposition=inline%3B%20filename%3DScribe4Me_Evaluating_a_mobile_sound_tran.pdf

ISEEWHATYOUSAY captures spoken language on a smartphone, converts it into text, and sends the text via Bluetooth to a remote user's device. The company offers a specialised receiving device about the size of a flash stick, and has begun to offer apps to receive the text on smartphones and wearables. A huge segment of the deaf and hard of hearing community is made up of elderly people who lost their hearing later in life and retain the ability to speak

Transcence uses a speech recognition algorithm to detect individual voices while multiple people are talking at once. It assigns each person a different colour when transcribing speech to words, so the user can more easily follow group conversations.

To support communication between deaf BSL users and hearing people, researchers are working on real-time translation from speech to sign language and vice versa.

Speech-to-sign translation involves speech recognition, semantic interpretation, and sign language synthesis as animations of virtual humans. Sign-to-speech translation involves gesture recognition from camera or gloves, semantic interpretation and text-to-speech. Most of these components except semantic interpretation are fairly mature²⁰.

Implementation of sign recognition without using external devices (such as haptic gloves or special cameras), however, remains challenging as input from the device's camera needs to be processed to correct for factors such as angle, zoom, lighting and so on. Therefore, most current apps can only produce sign language as output, and not use it as input.

"Say It With Signs" allows telephone communication between hearing and deaf people, when text messaging is not available to the hearing person. By using voice recognition technology, the phone can convert audio into digital hand signs which will be displayed on the receiving mobile phone screen. The deaf person can then reply through text message, which will be converted into an audio clip

iCommunicator provides real time translation of speech to text, speech or text to sign language (video), and speech or text to a computer generated voice

Eye sign is a translation app which turns written or spoken English into BSL. Users can set up a named chat, and then input English either by typing it in the box provided, or by using the speech to text function. This takes spoken English, converts it to text and then translates that text to BSL

SL translation service is a web service which translates text into sign language using a virtual signing agent²¹.

To the best of our knowledge, there are currently no apps able to recognise sign language reliably. The self-proclaimed first two-way communication software for deaf people is the

²⁰ http://hclilab.uniud.it/images/stories/publications/2010-06/DeafCommunication_MobileHCI2010.pdf

²¹ <http://www.ra.ethz.ch/cdstore/www2012/w4a/02%20-%20Communications/boulares.pdf>

American designed, **UNI**²² which uses specific hardware (a tablet with specialised camera) to track both hands and all 10 fingers to convert American sign language into speech. The software's dictionary can be expanded with customized signs added by the user. There is also an option to upload those signs to the Internet, to share with others. The hearing-to-deaf half of the communication happens via speech to text.

4.4 Alerting to sound

Tap Tap detects noise (for example door knock, alarm) and subsequently flashes and vibrates to alert the user.

The **Convo Lights** app developed for Philips Hue uses light to notify deaf people of phone calls and other audible signals that they could normally miss. The app allows users to create personalized ringtones of light to identify incoming callers, and adjust the brightness in a room to make sign language easier to see onscreen.

The company **OtoSense** develops sound recognition software on the Android TM platform; it developed an app, which has the same name as the name of the company, to enhance the personal safety and quality of life of deaf people. The app is capable of recording any sound around a deaf user and notifying the user via flash, vibration or SMS text.

Hearing Aide focuses on safety - upon hearing a pre-programmed warning sound, the phone alerts users to the danger through 20 second vibrations and a message. There are five standard alarms already set, such as fire alarms, crying babies and boiling kettles, but the app can also store further custom alarms.

4.5 Other

For those who are partially deaf, sound can be filtered and/or amplified by various apps such as **uSound**²³.

GP surgeries offer web-based portals to book and cancel doctor and nurses appointments, view and order repeat prescriptions and update personal details online, reducing the need to communicate verbally or in person.

While the above sections are mainly based on a review of peer reviewed and grey literature, in the next section we explore what is currently commercially available on the app store for people with sight loss, or those who are deaf or hard of hearing. We restricted our search to the Apple store since search results tend to be fewer and more relevant, and possibly of higher quality (due to Apple's review process), than on the Google Play store. We classified apps based on their features to see which app types are most common.

²² <http://www.motionsavvy.com/uni.html>

²³ <https://www.orcha.co.uk/review/5039/>

5. Apple App Store search

Given the much large number of apps turned up by a Google Play search, the initial app search was confined to Apple's App Store. The search terms used on 21-23 November were 'blind', 'sight loss', 'deaf' and 'hearing' (capturing hard of hearing and hearing impaired). A database of apps is provided in the accompanying excel spreadsheet.

Features of apps for those with sight loss, in descending order of number of apps found:

- 20 object recognition
- 13 navigation
- 11 OCR
- 8 apps colour recognition
- 8 magnify/filter
- 8 test sight
- 4 writing/typing
- 4 time/alarm
- 2 detect light
- 2 crowdsourced solution
- 1 phone interaction
- 1 social.

Features of apps for the hearing impaired, in descending order of number of apps found:

- 30 test hearing
- 18 augment sound (for example increase loudness, filter)
- 7 control hearing aid
- 6 learn sign language
- 5 communication
- 3 books in sign language
- 2 alert
- 1 subtitles for TV
- 1 accessibility info travel (London).

6. Summary and questions for future research

The above rapid literature and market review highlights that there are very few papers in the literature and no apps that deal specifically with mobile health for adults with visual or hearing impairments. There are, however, a wide range of publications and apps dealing with features (though not built explicitly for this purpose) which may facilitate interaction with the healthcare system.

From the point of view of those who have sight loss, apps that help with navigation, and object and text recognition may be most useful. From the perspective of someone with hearing loss, communication apps, especially speech to text and BSL apps may be able to have the largest impact on interaction with healthcare services. Ideally, decisions about which app features are most helpful should come from sight and hearing loss users themselves, for example via interviews, asking them about their frustrations when interacting with the healthcare system. Further steps can include more in depth research on identified features of interest and evaluating existing apps, including a theoretical checklist and/or testing with users.