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Chapter

Smartphones for Vision Rehabilitation: Accessible Features and Apps, Opportunity, Challenges, and Usability Evaluation

Suraj Singh Senjam

Abstract

In today's world, digital technology and smartphones have become a part of our everyday lives. Smartphones are one of the most advanced forms of digital technology that can be viewed as assistive technology for disabled, including for individuals with a visual loss. However, they are often not considered as assistive technology for visual impairment and blind, especially in low middle-income countries. There have been a lot of development in the mobile technology that incorporates computer technology, including electronic information, communication technology as well as touch-screen accessibility. Such an advancement in smart technology of mobile devices leads to the transformation of the interface technique from visual smartphones interaction into a truly eyes-free means interaction by using other body senses, such as haptic, gesture, and sound, etc. These innovative accessible features and applications enhance the accessibility of smartphones significantly to individuals with visual impairment. There are many built-in accessible features and third-party accessible applications that enable to access many useful information and contents in the smartphones. Such aesthetic technology facilitates in performing daily activities, independent functioning, movement, social inclusion and participation, educational activities, accessing information of today's digital society, sighted help, and finally helps to improve the quality of life. Therefore, these smart technologies make smartphones to serve as assistive technology for people with visual impairment and blindness. The smartphones are visually and physically demanding, and are ubiquitous any time and any place, and user can carry it at everywhere. They are universally design, so less social stigma to the users and less discomfort when using it. To view smartphones as assistive technology universally, healthcare providers, caregivers or rehabilitation professionals need to be informed, and make aware of the beneficial aspect of smartphones and its accessibility. Finally, engineers and developers are continuously fostering to develop more innovative and readily accessible apps for visual impairment. Since single app does not fit all purposes for visual impairment and blind, there is a potential need of developing clinical guidelines on the use of such accessible apps or features that will help to recommend appropriately for various types of functions.

Keywords: smartphones, accessible applications, visual impairment, usability evaluation, vision rehabilitation

1. Introduction

The World Health Organization classifies the blindness as a severe disability that corresponds with its category VI, whereas the category VII is considered to be a maximum severity [1]. Visual impairment and blindness are problems which can affect significantly in functioning for daily living activities, to live with independent life, indoor and outdoor movement, social inclusion & participation, communication, employment, and finally impacted on the quality of life [2–4]. Such impacts extend much beyond individuals who have the problem, but also to the family, to the society as well as the community to a large extent. In addition, the present COVID-19 pandemic and its preventive measures pose a new challenge in terms of performing the daily living tasks among visually disabled people as well as to receive their daily supports for living [5]. Globally, around 253 million people who have some form of visual loss are facing such challenges and difficulties in their everyday life [6]. These people need to live with independent lives, and cope these daily challenges and difficulties resulting from visual impairment whether it is at home, workplaces, schools, or market. Fortunately, the continued advance in assistive technology has provided a new platform and opportunities for people living with visual impairment to overcome many of these barriers and challenges that they encounter in their everyday lives. Digital assistive technology is one of them that has grown rapidly in the past few years which helps in solving these challenges.

Many smart digital assistive technologies based on electronic information, communication technology for visual impairment have been gaining a lot of importance across the world in recent times [7, 8]. Such smart assistive technologies have many accessible features and accessible applications for persons with disabilities, including low vision and blindness. For instance, the technology of mainstream assistive devices, e.g., mobile phones and tablets, has evolved substantially over the years from simple basic phone, such as NOKIA 8110, to high end and touch screen smartphones or tablets or I-pad with operating system of IOS, or Android platform (Figure 1). With ongoing advance in smartphone technologies, it is becoming even more feasible for the person with visual impairment to rely on mobile technology in understanding their immediate surrounding, and to access huge amounts information that can improve their level of independent functioning, movement, social inclusion, participation, educational activities, and finally helps in improving the

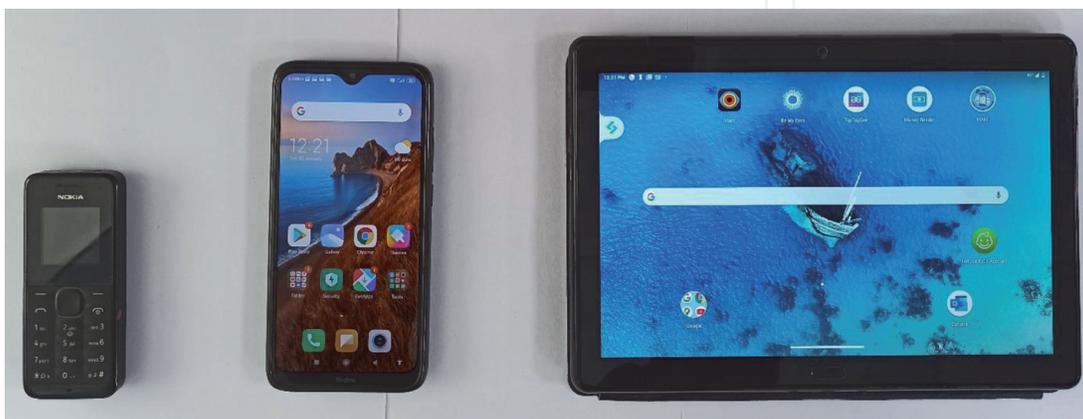


Figure 1.
Simple phone, smartphone, and tablet (left to right).

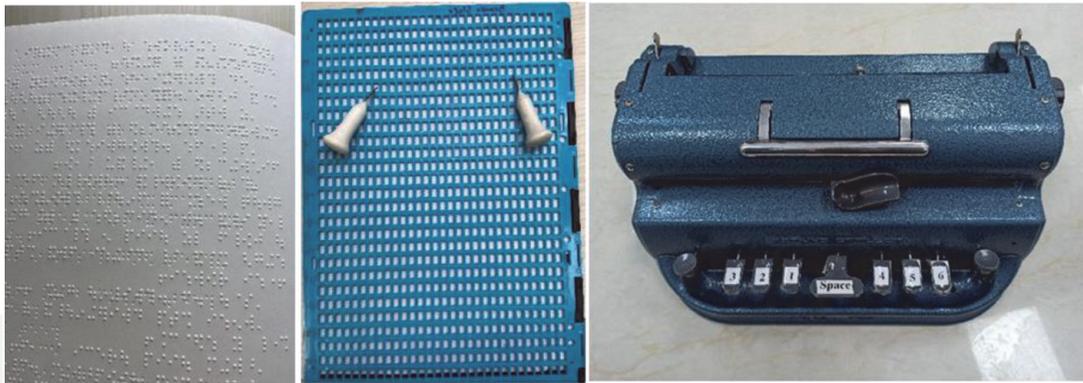


Figure 2.
Braille book, Braille slate and stylus, Braille type writer (left to right).

quality of life [9]. Now, smartphones have become a part of our everyday life and replacing gradually the traditional assistive devices (such as Braille materials **Figure 2**) in doing various routine tasks and bringing the solutions [10, 11].

2. Smartphones assistive technology for persons with visual impairment

Conventionally, people and even health care providers, frequently, do not consider smartphones as assistive technology for visual impairment and blindness [12, 13]. Since, the smartphone technology heavily relies on a good visual function, many believe that such a technology is not particularly accessible to individuals with visual impairment. There is perceived limitation on the use of smartphones among the general public, eye care professionals, and caregivers, by visually impaired people.

Over the last few years, the research on “Human-Computer -Interaction” has been gaining a lot of attention, and have been developed many innovative assistive technologies that drive with a new interface design which not only makes more accessible, user-centered but also user-friendly for visually disabled people. Such

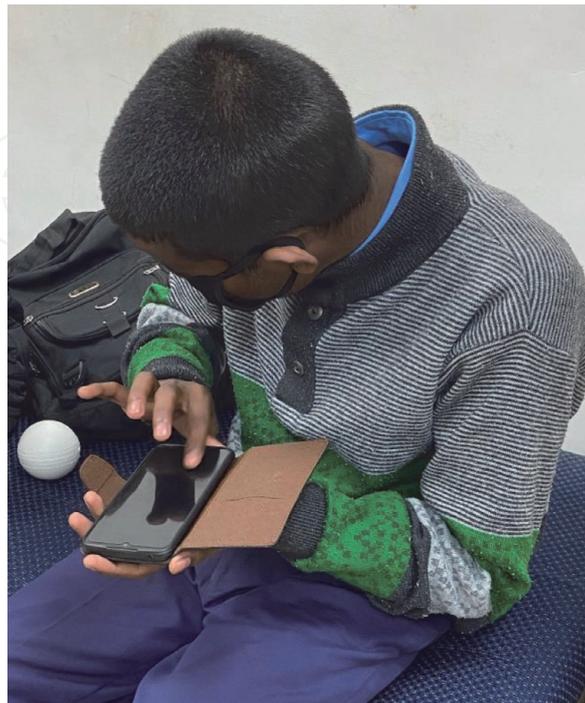


Figure 3.
Eyes-free smartphone interaction using gesture.

remarkable changes in assistive technology development transform the need of visual interaction to audio or haptic or tactile interaction with the technology. Till now smartphones are one of the most advance features of computer technology of the 21st century, that contain many functionalities of advance computer technologies, including technologies related to electronic information and communication system. Various innovations on usage of other body senses, for example, gestures, haptic, or audio, other than vision are being developed, making a truly eyes-free means in human smartphone interaction (**Figure 3**), and thereby, significantly improve accessibility to individuals with visual impairment. The smartphones have a large touchscreen system to run it, and can access mobile internet data, Wi-Fi and Bluetooth. Such an innovative touch-screen accessibility leads to an obvious benefit to visually challenged individuals, and also helps to overcome many challenges. The common operating systems of smartphones are based on the Android, Apple iOS and Windows phone, BlackBerry; Android being the most common, 59.1% in market shared [14].

3. Accessible built-in features for visual impairment and blind

There are built-in accessible features in smartphones that facilitate for all users regardless of disabilities or individuals' functional limitations. These accessible features enable a person with a disability to interact with the contents in the smart mobile phones [15]. A large number of accessible built-in features have been developed specifically for people with blindness and visual impairment. Few examples are highlighted in **Table 1**. These features have been preserved mostly on Apple iOS and Android operating platform, contributing more than 90% of the world smartphone market [16]. The most widely used built-in accessible feature as screen readers are TalkBack for Android (**Figure 4**) and VoiceOver for Apple iOS (**Figure 5**) among people with visual impairment [17]. The Talback feature allows the user to easily identify the content or applications icons on the smartphones' screen with a verbally speak words or voice from the device upon touching with fingers on the icons. By simply placing a finger on the icons, the smartphone will read aloud what icon is

Features	Operating system	Operating mode	Descriptions
Voice assistant (Google assistant, Siri)	iOS/Android	Audio based	Ask it a question. Tell it to do things
TalkBack	Android	Audio based	Screen reader
VoiceOver	iOS	Audio based	Screen reader
Text to Speech/Voice recognition	iOS/Android	Audio based	Read aloud
Select to speak	iOS/Android	Audio based	Select to speak, Speak selection
Zoom magnification/Font size	iOS/Android	Visual based	Zoom in the display
Contrast	iOS/Android	Visual based	Differences between an object and its background.
Invert colors	iOS	Visual based	White becomes black, black becomes white, orange becomes blue.
Voice Inputs Keyboards	iOS/Android	Audio based	Typing through voice command

Table 1.
Accessible built-in features of smartphones.

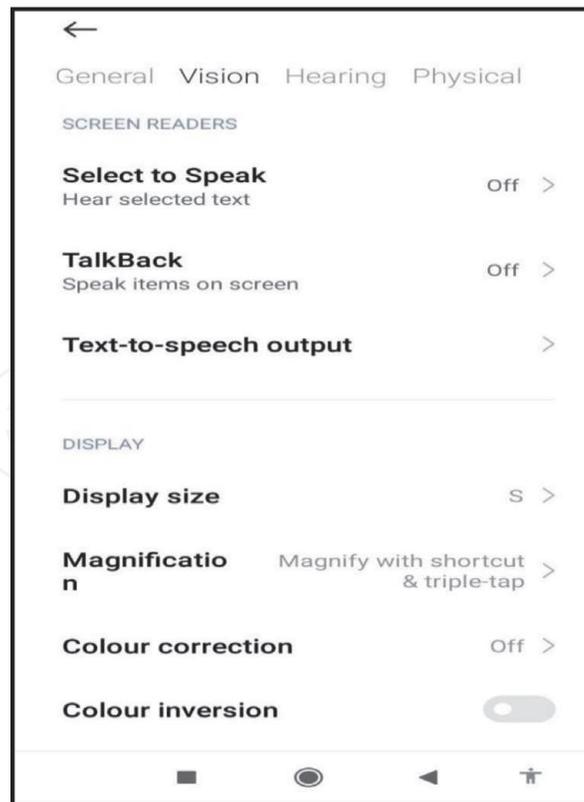


Figure 4.
Built-in features in Android operating system.

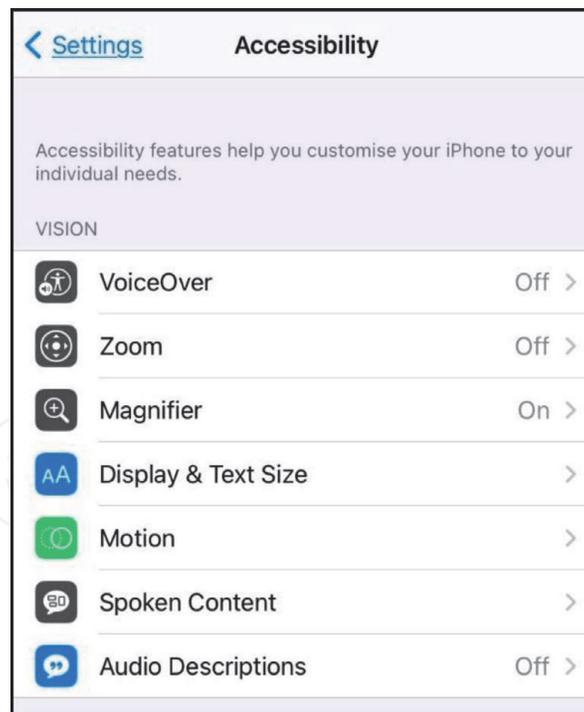


Figure 5.
Built-in features in iOS operating system.

underneath the finger. Similarly, VoiceOver provides voice feedback aloud what appear on the smartphones' screen, so iOS operating smartphone can be used without the need of visual function. A visually disabled individual can slide around on the screen with finger until the desired icons is located.

This feature provides unwavering support to perform activities of daily living, communication, social interaction, for a severe visually impaired or blind users,

where human-vision smartphone interaction is impossible or difficult. For a person with a low vision, the zoom magnification feature helps to magnify the entire screen to the required level of individual's choice. Invert colors allows to change the white text on a black background, and vice versa or blue text on a yellow background. A study on iPhone accessibility features in visually impaired population shows that the Zoom Magnification and Large Text were the most common use features among people with visual impairment [15]. This study reported that many participants were interested to use other accessibility features if they are familiar and trained on how to use such accessible features of a smartphones.

4. Third party accessible applications for visual impairment and blind

Generally, people believe that smartphones are inaccessible to people with a visual impairment; visually disabled people will face a lot of difficulties when they use for their everyday lives. This is because, operating smartphone is based on touch screen which is relied largely on good visual functions. When human-digital

Apps	Operating system	Operating mode	Descriptions
Kibo	Android	Audio based	Image reading, (pdf, e-book, doc, reader Hindi & English both)
Be My Eyes	Android, iOS	Audio based	Help by Sighted person (volunteer) through video calling
Supersense	Android, iOS	Audio based	Information about surrounding, Artificial intelligence (AI)
Visor	Android, iOS	Video based	Magnifier (Near objects)
Binoculars	Android, iOS	Video based	Distance viewing (Super zoom camera)
Mani	Android, iOS	Audio based	Mobile Aided Note Identifier
BlindSquare	iOS	Audio based	Navigation, search places, etc.
Khabri	Android	Audio based	Audio news, current affair, job, horoscope, stories, and promotional podcasts Hindi, etc.
Phonepe or Google Pay	Android, iOS	Audio based	Easy and reliable way to make hassle-free payments online, E-Transaction
AccessNote	iOS	Audio based	Note taking
KNFB Reader	Android, iOS	Audio based	Its text-to-speech, text-to-Braille, and text highlighting tools make it valuable for blind
Blind Bargains	Android, iOS	Audio based	It brings you the latest sales, deals, and news on computers, screen readers, notetakers, Braille printers, hard drives, accessible cell phones, memory cards, talking products, household items, and much more
Seeing Eye GPS	iOS	Audio based	The Seeing Eye GPS, is a fully accessible turn-by-turn GPS iPhone app with all the normal navigation
Bard Mobile	Android, iOS	Audio based	It allows you to download and read audio books from the National Library Service (NLS) for the Blind, but needs to register in NLS
Audible	Android, iOS	Audio based	It provides a lot of audio books for people with visual impairment and blind

Table 2.
Some accessible applications for visual impairment of smartphones.

technology-interaction i.e., interface, is depend on vision, then visually impaired people face a tremendous limitation to access all kind of the information present in the smartphone. With ongoing advances and sophistication in mobile technology, the smartphone can be operated with eyes-free interface in an efficient way. These accessible applications are based on audio and tactile/haptic based interaction substituting the need of visual based interaction. There are many “apps” available that are accessible to people with visual disability. Few examples are given with a brief description of each in **Table 2**. **Figure 6** represents illustrations of few accessible apps. Majority of these apps are freely available online, so a visually impaired person can download, and install any specific app for their purpose.

These applications enable the smartphones serve as assistive technology for visually impaired people and facilitate to do tasks related to independent living, performing daily activities, to engage in education, societal activities, help in access information in today’s digital society, sighted help, and to improve the overall quality of life. For example, the “Kibo” application helps an individual with a visual disability to access all electronic prints or pdf files or word document files (**Figure 7**); Be My Eyes for sighted help; Visor for color inverts; Mani app for currency identification and RightHear for navigation.

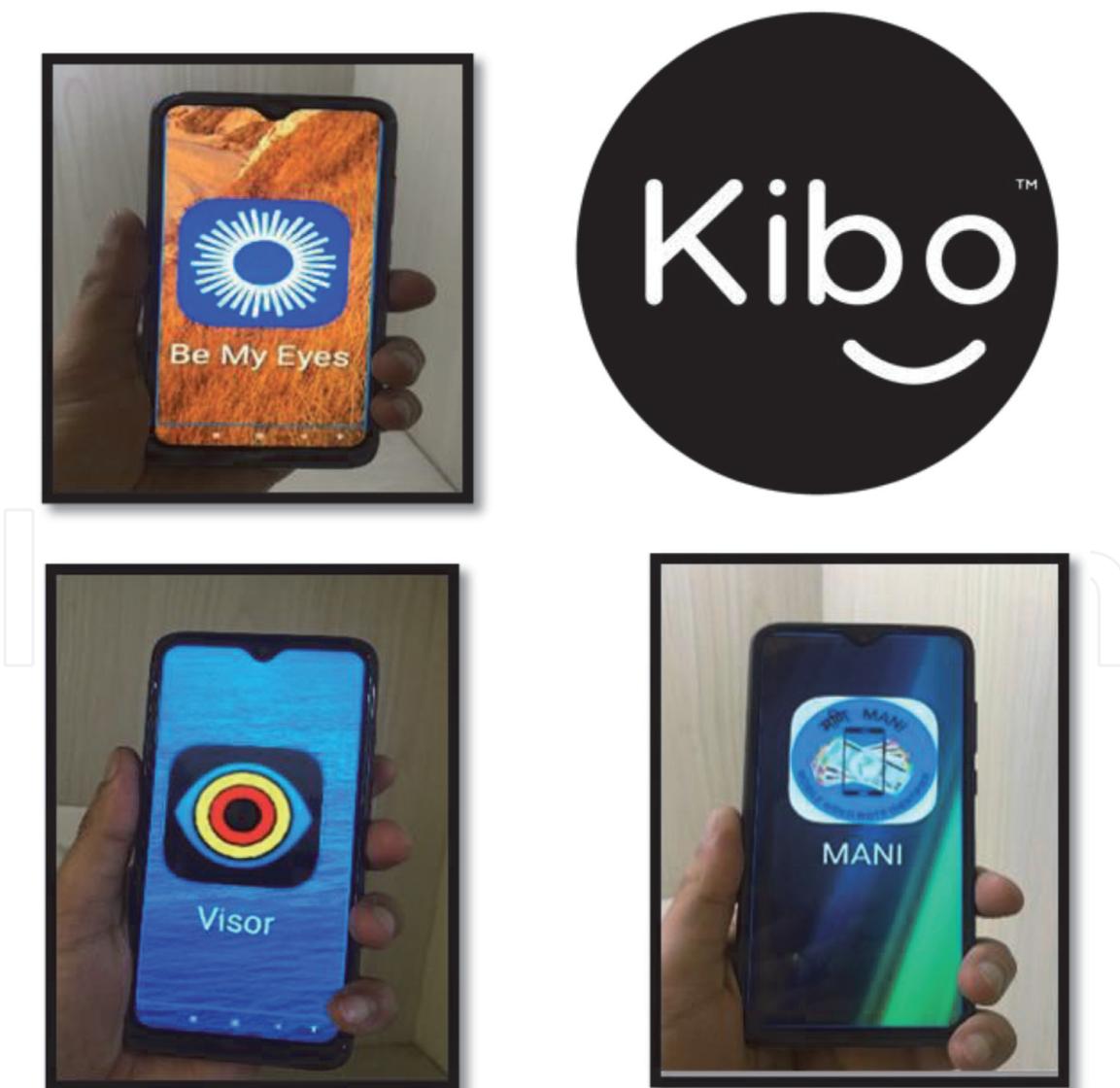


Figure 6.
Third Party accessible applications.

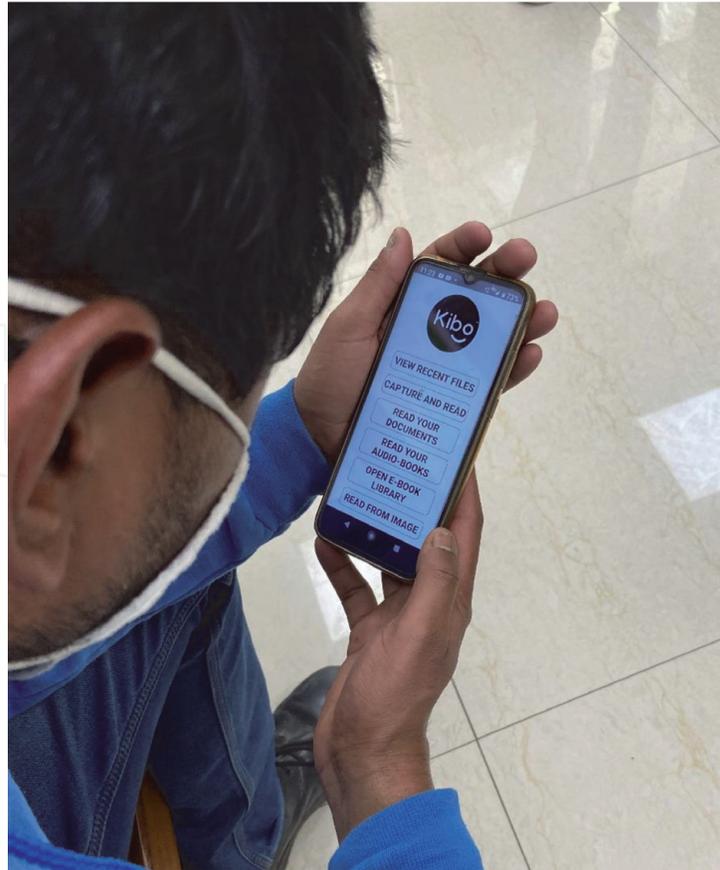


Figure 7.
Kibo accessible application.

5. Use among visually impaired and blindness

Smartphones, both its accessibility features and applications are being used for a wide range of daily living tasks that might have executed previously with the help of traditional assistive devices, e.g., magnifiers. The operating system can download a third-party accessible application to have a customised functionality. These accessible apps can be used for object and obstacle identification, sighted help, communications, emailing, reading e-Book and writing (Access Note, Be My Eyes, KNFB Reader, TalkBack, Braille Touch), news reading & listening (AccessWorld, Blind Bargains), entertainment, calendar functioning, currency identification, GPS navigation (Mani app, BlindSquare, Seeing Eye GPS) social networking, recording memos and color identification, talking calculator, so on.

An exploratory study on smartphone use among people with visual impairment shows that more than 90% of respondents used their mobile for activities such as calls, sending and receiving message, browsing the web, reading emails; 70–80% of them used smartphone for calendar functions, listening music and social media, and networking; 60 to 70% of them used for reminders and to take photos for reading with Optical Character Recognition [18]. This study also shows that 80% of participants used a smartphone for outdoor GPS navigation. An online survey conducted in a developed country in 2014 reported that 81% of respondents with a visual impairment used smartphone apps for various routine activities [19].

In a global survey on the use of accessible apps, more than 95% of people with visual impairment reported that these special apps were useful, and being used to accomplish their daily activities [20]. The most frequently use apps were Be My Eyes, ColorID, CamFind, followed by screening reading and writing apps, e.g. TalkBack,

KNFB Reader BrailleTouch. The study population of this global survey highlighted about the satisfaction of these special accessible apps of smartphones. In many cases, the smartphones apps can function for multipurpose tasks that facilitate independence living. Natalina et al. study also highlighted that the smartphones are replacing many traditional assistive solution to a great extend in doing daily activities [18]. A few studies reported that participating in digital arenas and accessing digital technology, including smartphones, reduce loneliness feeling, improve social contact, information sharing, gaining a better interaction with friends and family [21–23].

A study on tele-rehabilitation services for visually challenged students, in which smartphones were used exclusively, reported that smartphones based tele-health services offer a safe and an efficient way of providing all reliable information of COVID-19 pandemic, including various preventive strategies among students with visual disability. Such a tele- health services help to avoid the direct face to face contact between providers and patients. The study also highlighted such a platform helps in psychological counseling for fear and panic, facilitating and addressing the many unseen challenges faced by visually disabled people during the lockdown and pandemic period [24].

6. Advantages in using accessible features and applications

Conventionally, patients with low vision and blind receive optical and non-optical vision rehabilitation services using various traditional assistive devices such as magnifiers (both near & distance) and Braille, Digital Accessible Information System (DAISY) book and video magnifiers or Closed Circuit Television -CCTV (Figure 8). Although, the beneficial for traditional devices are widely documented in literature, their adoption and consistent use amongst visually impaired individuals is impeded by various factors, such as, discomforts, expensive, weight, difficult to carry, social stigma attached to it, lack of technical support in terms of training, lack of skills and knowledge in caregivers, unavailability [25–27]. For example, the cost of CCTV is 1000 USA dollars or more. Therefore, non-procurement by visually disabled is likely to be high. At the same time, the abandonment and disuse of these traditional devices are ranging from 30%, reaching upto 75% for few devices [28].

Mainstream smartphones are visually and physically demanding, and are well adopted by general population across the world, therefore when an individual with a visual loss uses a smartphone, the users are less likely drawn to public attention in comparison with traditional assistive devices. Furthermore, they are less likely to pose a social stigma while using them, less discomfort to use it and seldom have any



Figure 8.
Traditional assistive technologies (left to right: CCTV, Optical magnifiers, DAISY)

negative peer reaction on the users. As evidence exists on the influence of stigma and social negative reaction on adoption of traditional assistive devices in people with visual disability [18, 29].

In addition, the smartphones are available any time and any place, and universally design and user can carry everywhere [17]. The portability of smartphones with a lanyard or holsters is an important advantage as reiterated by visually impaired population. Their cost is relatively lower in prices compared to earlier periods. Therefore, the mainstream devices are replacing the traditional assistive devices in performing multiple daily living tasks, though the traditional devices are still in use for a limited specific purpose [18]. A study highlights that independent living, accomplishing daily living tasks will be better function in a person with visual impairment with app than without app [30].

The smartphones can be connected with the internet Wi-fi, Bluetooth for various purposes, further the accessible features and apps help to access various useful information. Such advance technologies help to accomplish a lot of activities from home avoiding the needless travel among the users. The new wireless charging system for smartphones is recently added on characteristics which can help to recharge the battery. With a new norm after COVID-19 pandemic, the smartphones and accessible apps help in availing tele-rehabilitation services provided by eye care centre [31, 32]. Such tele-health service help to avoid the unnecessary travel to the hospital and maintain social distancing during the lockdown.

7. Challenges in practices and application

As of today, many of us do not view smartphones as assistive technology for visual impairment. One of various reasons for it is, the healthcare providers, caregivers, even eye care professionals have a lack of awareness and understanding of the beneficial aspects of such smart mobile technologies, resulting in a lack of recommendation [33]. There are hardly any studies available about awareness on accessible apps among eye care providers or caregivers. Such studies are needed in the future while addressing the issues. Increasing accessibility and access or use of smartphones in persons with visual impairment requires sensitization and making understand the mainstream eye care providers, medical practitioners, including primary health physician, caregivers, family members at the fore front, even to a large section of the community. Therefore, digital literacy and providing information on accessible applications and features are required at all level health care delivery or hospitals, community, before generating awareness and skills development amongst beneficiaries. Accomplishing these activities should be one of the priorities of the vision rehabilitationists or low vision specialists, medical social workers, formal and informal community-based organization delivering services to visually disabled people. In this, the integration of assistive technology services for visual impairment, including smartphones into eye care practices or other related services for disabled could be worthwhile. There is a need for involvement of multiple sectors for such a large-scale activities, since involving only health sector is less likely to be a successful strategy. For example, educational sector for generating awareness among teachers, students; Information and Technology sector for enhancing learning, communication channels, labour market for easy availability, etc. should be involved in the awareness activities.

In addition, the relevant ministerial divisions of a country should have a policy to address the gap in the services of assistive technology for visual impairment, including smartphones and demands in their respective countries. International organization like The World Health Organization, Global Alliance for Assistive

technology, UN convention for Rights for persons with Disabilities can support countries' policy and planning for assistive technology services, including service related to smartphones for disabled as a whole.

The number of accessible apps and accessible features are continuously growing over time for people with visual impairment. Designers are continuously fostering to develop more innovative and readily accessible, and user-friendly apps for visual impairment. These may lead to complexity on use of apps, since each app has a special function though some functions are overlapped. There is not a single app that fits all purposes. Therefore, initial assessment of the requirement for the apps will be required and followed by tailoring the training program to meet the specific needs. There is a need of developing training guidelines on use of such accessible apps or features that will facilitate to recommend appropriately for various types of functions and vision loss, e.g., reduced vision acuity, visual field loss, reduced contrast sensitivity or clinical findings. Using multiple apps in a smartphone may consume more power from the battery. So, there is a need of a good quality battery to operate extended periods of time, especially for smartphones used by visually impaired people. A due attention to improve awareness, on digital training, data security, back-up in the event of lost or theft of smartphones could be challenges among people with visual impairment.

8. Usability evaluation for visual impairment

People with visual impairment have a unique requirement to be able to interact with smartphone assistive technology. Such a unique requirement can cause a gap between the ideas of the developers of smartphones and the needs of individuals with visual impairment, leading to either a lack of adoption or abandonment of smartphone. There is an obvious need of collaboration between vision rehabilitation professionals and expertise in computer sciences and involvement of visually challenged individuals, and their participation, in designing an innovative, acceptable, and adaptable mobile assistive technology that will assist to develop a user-centred technology.

Therefore, usability testing or evaluation while developing of accessible features and apps for smartphones is essential so that the features and apps are accepted and adopted by the end users. For examples, a smartphone may have many built-in multiple functions, but if it may not be usable to target population due to inaccessible or discomfort on use. A systemic evaluation on the usability testing should be a part of developing for accessible features and applications of smartphones.

Usability is an elusive concept. To define it explicitly, we have to devise measurements that reflect the user's experience of a product and the level of success we establish for the product. As a working definition, usability is the ease with which people in a defined group can learn and use a product. The characteristics of and relationships among the *tasks*, the *users*, and the *product* determine the product's usability.

S. Rosenbaum Dec. 1989

The potential gap between the unique experiences and challenges faced by people with visual impairment and ideas of designers are crucially important. The designer needs to understand the user-centered and user-friendly perspective while efforts have put in to develop various apps as assistive technologies for visual impairment, that the developers create the apps that meet the user's expectation and needs. The product should be designed that a person with a visual loss can access all accessible features or functions that they want to execute. There is a need for evaluation and testing whether there are any usability problems in using the features and applications by end the users.

Designers or ergonomics engineers may face various challenges to perform usability evaluation for assistive products in an efficient way. Several factors may account for this, such as multiple influencing factors, so many non-specific tests and evaluation methods. There are methods available to do usability evaluation for assistive technology. Among them, Kwahk and Han has designed a simple usability evaluation framework of the electronic audio-visual products that can help the evaluators while conducting usability evaluation of their products in rational way (Figure 9). The framework is not specifically designed for smartphones apps and features, but the principles can be applied to other categories of assistive products with a minor change as per product designed. The framework provides a concise model how the evaluation should be done based on four parameters, i.e., first, user information; second, products information; third, user activity information; and fifth, the environment information [34].

The user information is important when the product is targeted at the users with special needs, for examples, individuals with visual disabilities or any other physical disability. The product information is required to understand the context of evaluation, for examples, form of the products- paper-based descriptions, mock-ups of the products or computer-based prototypes or finished products, etc.; level of the products in terms of perceived value: high-end, mid ranges, low end, etc. The environment and socio-cultural factors are also influence the user’s operation and performance of the products.

Kwahk and Han further described five different techniques for evaluating usability of a product in human-electronic devices or computer- interface areas. The evaluator can select the suitable technique as per the context of the product and feasibility for conducting. They are as follows:

1. Observation/inquiry techniques

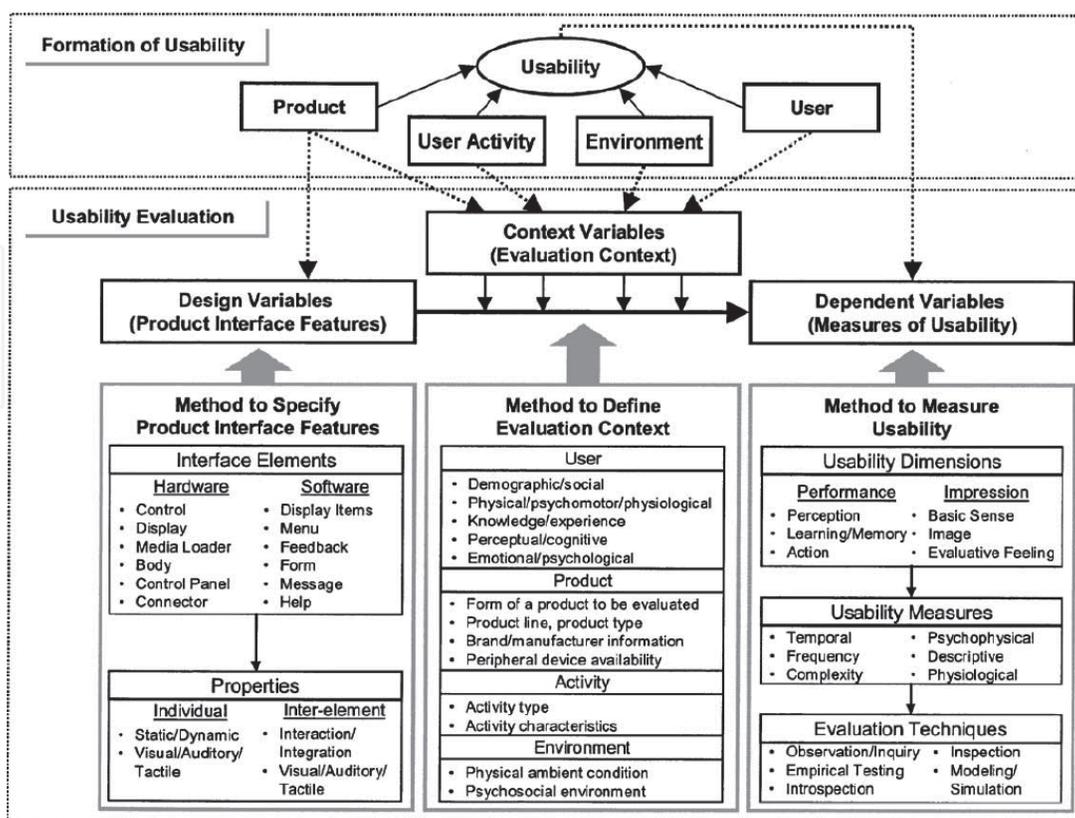


Figure 9. Usability Evaluation Framework for electronic audio-visual products. (Source: Kwahk and Han [34]).

2. Empirical/usability testing
3. Introspection technique
4. Inspection methods
5. Modeling/simulation methods

The detail of each evaluation technique is beyond the scope of this book, but a brief description is given here. The empirical or usability testing with real users helps the designers to understand the experiences and challenges faced by people with disabilities while using assistive technology. Therefore, a designer can stress on empirical testing of the products [35]. Think-Aloud protocols are a dominant method in usability testing. There are two Think-Aloud techniques for usability testing that use commonly by the usability specialist; A Concurrent Think Aloud (CTA), in which experts request the participant to verbalise their thoughts as they perform the tasks with the help of the devices. Experts also use Retrospective Think Aloud (RTA), where participants are asked to retrace their steps after they complete the tasks and share the challenges [36, 37]. There are the pros and cons of both protocols, so expert has to decide which technique is suitable for usability testing.

Usability testing is the practice of testing how easy a design is to use with a group of representative users or persons with disabilities. It usually involves observing users as they attempt to complete tasks and can be done for different types of product designs. It is often conducted repeatedly, from early development until a product's release.

The goal of both usability evaluation and usability testing is the same: to improve the usability of products or assistive technology.

The introspection technique is an effective method to rule out the basic causes of usability problems based on user's thought and feeling. Often, evaluators might have difficulty to identify the cause of usability problems. This is because the evaluators have not imagined these problems that people with disabilities would have encountered while using the assistive products. Identifying the causes of usability problems helps the evaluators to differentiate whether the problems are due to individual's disability or by imperfect interface design for the assistive products [38]. For example, a study conducted by H K Kim et al. on identifying interaction experiences of visually impaired people when they use with smartphones, the common usability problems encountered are shown in **Table 3**. The study indicates that the problems vary according to the severities of visual impairment.

Usability evaluation	Usability testing
<p>An <i>expert evaluation</i> is an assessment of the product's usability by an expert in usability issues, called a usability specialist. An expert evaluation, a usability specialist carries out an evaluation process that combines investigation of a product's specific user audiences and tasks with in-depth knowledge of general usability rules and measurements.</p>	<p>A <i>usability test</i> enables us to quantify the extent to which a product meets the needs of its intended users. Working with subjects selected as having the target users' point of view, the test consists of tasks designed to attain specified objectives consonant with the type of product and the characteristics of its users.</p>

Usability problems

Performance of recognizing faces is lower than I expected
 Difficulties of using the horizontal mode
 Difficulties of finding the menu
 Speech too slow
 Color contrast
 Difficulties in typing with a QWERTY virtual keyboard
 Recording TalkBack sound along with my voice
 Difficulties of understanding the location of a face on the screen
 Correct pronunciation
 Narrow touching area of menus
 Screen reader voice unfriendly
 Difficulties of selecting a shooting button
 Beeping sound lasts too long
 Difficulties of memorizing the interface layout
 Need the function of voice pause
 Need the function of voice stop
 Difficulties of understanding the direction to move the camera
 Locating similar menus too far
 Menu buttons too small
 Difficulties of inferring the word of big and small face
 Speech too loud
 Difficulties of using a sensitive touch interface
 Need additional menu titles along with icon for first-time users
 Too long photo title which is automatically inserted
 Transparency of background
 Font shape
 Difficulties of recognizing the meaning of icon designs
 Need more color combinations of text and background
 Need bigger text size
 Complex interface layout
 Need informing the existence of sub-menus
 Beeping sound pitched too high
 Space between letters and lines
 Stroke width
 Need higher recording quality

Source: Kim et al. [38].

Table 3.

Usability problems identified in the study among visually impaired people.

9. Conclusion

Individuals with visual impairment and blindness face various challenges and barriers in their everyday lives. These people need assistive technology to overcome these challenges and perform a wide range of daily activities, including reading and writing. These technologies vary from low technology to high end and specialized technology, including software programs. In the recent times, mobile technology has gained a lot of attention across the world and are incorporated many advance computer and information technologies features.

Smartphones, the most sophisticated mobile technology, have been developed as smart assistive technology for people with visual impairment in the few years with many accessible built-in features and accessible applications with the help of sound, haptic and gestures interaction, instead of vision-smartphones interaction. Such innovative accessible, user-centred and friendly technology has provided a new platform and opportunities for people living with visual impairment to overcome the very challenges and barriers encountered in their everyday lives. Many

accessible apps have been shown to be of great value and support in performing a wide range of daily living activities in people living with visual impairment. Such technologies are less likely attached with a stigma compared to traditional assistive devices. Further, use of smartphones have certain advantages, such as easily portable, less discomfort on use, relatively low cost compared to some of traditional devices. With widespread availability of mobile technologies along with eyes-free human smartphones features and applications, there might be a corresponding need of developing a clinical guideline on the use of accessible features and applications.

10. Recommendations

Now days, smartphones become a part and parcel of everyone lives, irrespective of health or disabilities. As of today, smartphones are asset of the general population who are sighted. However, with the help of accessible apps and built-in feature developed in the past few years, people with visual impairment and blindness can access smartphones and use for varied purposes. Now, it is time to scale up its use among visual impairment and blindness. Therefore, there is a strong need for sensitization, promotion of smartphones as assistive technology in health or eye care facilities across the globe, even in educational institutions. Integration of smartphones services as assistive technology for visual impairment, in all eye care practices, but not limited to vision rehabilitation, would be helpful in improving the accessibility of it. Considering the demand as well as requirement for smartphones among people with visual impairment, a strong and effective advocacy is the need of the hour, especially in low middle income countries.

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