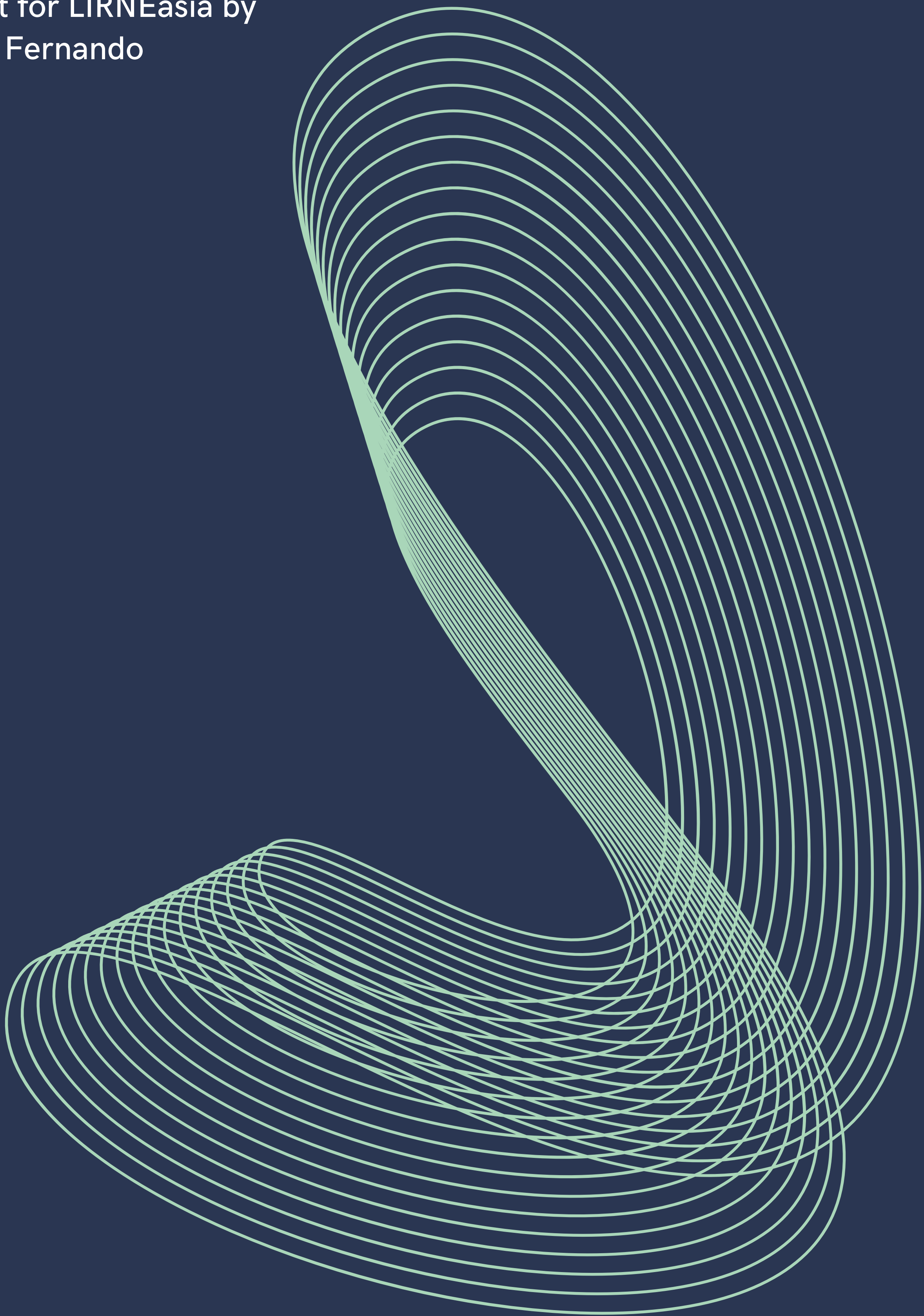
Assistive Technologies Aided by ICT

A report for LIRNEasia by
Dilshan Fernando



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EXECUTIVE SUMMARY

The two primary objectives of this report are to introduce a framework to assess and contextualize the Information and Communication Technology (ICT) based Assistive Technologies (ATs) that aid persons with disabilities (PWD), and to provide a comprehensive list of what can be considered as AT products with ICT components. The aforesaid framework is based on the Human Activity Assistive Technology (HAAT) Model which highlights that in disability, the technology should follow the activity-needs of the person rather than vice-versa. Therein the HAAT model emphasizes the need to understand the various activity classifications that are available to map out daily tasks of an individual, which consequently help to discern the technologies needed to assist them. Hence, this report follows the "basic activities of daily life (BADL)" and "instrumental activities of daily life (IADL)" categorization-structure in order to present the AT list in a simple, yet appropriate way, such that all listed ATs are designated according to the type of daily activity that they aim to assist with. Furthermore, the ATs are not listed according to their use, rather they are categorized according to the assistive technology involved. Therefore, the lists contained here follow the structure of a technological classification along with an activity designation.

The report begins with a discussion about the basic concepts involved, and ends with two chapters, one on inclusion-oriented technologies (education, financial and health) and another on emerging technologies for PWD, while ATs pertaining to visual, hearing and physical impairments fill the middle chapters. Two of the major limitations of this report are; firstly, the impossibility of preparing an perfectly overlapping AT list with its corresponding activity classifications since most of such connections are subjective where a formidable methodology does not exist in literature to the best knowledge of the researcher; and secondly, the impossibility of providing an exhaustive list of ICT-based ATs given the existence of an enormous variety of products in the market coupled with constant developments of the existing technologies.

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1. INTRODUCTION

1.1 Research Goals

This report aims to produce a holistic list of information and communication technology (ICT) aided assistive technologies (ATs) pertaining to three types of disabilities: visual, auditory and physical impairments. Given the existing ambiguity concerning the method of distinguishing various ATs and about defining what actually constitutes an AT in the first place, this report entails a discussion of some of the ATs outlined in order to provide the context of disability in which they are prescribed. Inevitably, the report also preludes with brief discussions about what disability means to LIRNEasia, what ATs are and how researchers should conceptualize the activities of daily living in order to connect them with appropriate ATs. Much of the discussion herein is enriched by an implicit, and sometimes a manifest, awareness about the patterns of disability exclusion in the Asia Pacific region where LIRNEasia has conducted its disability research.

1.2 Defining disability

Although defining what disability is not an aim of this report, it is still worthwhile to present concisely the way disability is understood in the context of LIRNEasia's programmatic theme of disability research. Defining disability is difficult still more due to its coincidence of medical and social connotations. This point is a recurring theme in the 'Disability Studies' literature. As Mitra et al. (2011) assert pertinently, "disability is complex, dynamic, multidimensional and contested" (Mitra, Posarac, & Vick, 2011; p.3;). However, it is crucial to emphasize the paradigmatic shift in the way in which the debate over disability as a concept as well as a "human condition" (Mitra, Posarac, & Vick, 2011) has shifted in the last few decades. As Harpur (2012) notes, identifying the "social constructed-ness" of disability in the UN CRPD itself, in contrast to the designation of it as just another medical condition that requires proper medical care, foregrounds the direction in which policy efforts to address disability should take place. Therefore, the "social turn" in defining disability provides the context for investigating disability as a social problem.

Goodley's (2011) account of the "Social Model" in Critical Disability Studies literature helps to clarify this distinction. According to Goodley, following many of the field's predecessors, disability is defined as a social condition; more precisely an "effect" of negative social circumstances (i.e., infrastructures, attitudes, policies, etc.) that consequently constructs the condition of "disabled-ness." The clear distinction to be made with regard to this socially constructed "disabled-ness" is the medical notion of "impairment" (e.g., visual, hearing, physical, intellectual, and developmental, etc.). For this version of medically-centered disability, physical or mental impairment constitutes the entirety of disability. Therefore, "disability" in this respect merely warrants suitable medical aid to "treat" the PWD, while crucially ignoring the entire dimensions of social accessibility, inclusion, and enabling policies. Recognizing this "social turn," LIRNEasia's research on disability have progressively inclined towards a more consummate social conception of it. Understandably then, assistive technologies (ATs) of which this report makes an outline of, do so in light of the social model of disability.

1.3 Defining Assistive Technology (AT)

Common perception tells us that ATs are those gadgets that should be assisting a person who needs assistance – in this case the persons with disabilities (PWD) – to make his/her life easier. However, this common perception ignores a vast array of modern technologies pertaining to the digital world and not to mention the highly advanced forms of technologies such as computer aided instruction, ambient assistive living, etc. As Lazar et al. (2017) correctly identify, mobile phone penetration in the Global South is no 'rich phenomenon;' but rather its connectivity reaches the most down trodden and poorest people in the concerned regions that bring about new possibilities in their lives. This background therefore prompts us to understand what ATs are in the first place.

According to Cook and Polgar (2014) – to whom much of the following conceptualizations owe to - two formal definitions of AT, which are commonly used, come from the United States Legislation "The Assistive Technology Act of 1998" as amended (2004) and from the World Health Organization (WHO). The US legislation defines AT as: *"Any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities."* Similarly, the WHO (2001) defines AT as *"any product, instrument, equipment, or technology adapted or specially designed for improving functioning of a disabled person"* (Cook & Polgar, 2014, p.2.). The US definition, according to Cook and Polgar (2014), is more inclusive of mainstream technologies than the WHO version.

However, on a critical note, Cook and Polgar (2014) emphasize that there are other researchers – such as Hersh and Johnson (2008a) (quoted in Cook and Polgar (2014) – who argue that these formal definitions link AT too tightly to a medical model, which highlights the use of AT to overcome limitations and improve function for the individual. What is intriguing in Cook and Polgar's vision of AT is their reluctance to tie up ATs to simply the technology portion of ignoring the social barriers associated with the concerned activity that actually constitute the condition of disability. Hence, Hersh and Johnson – according to Cook and Polgar – *"propose a definition of AT that is inclusive of products, environmental modifications, services, and processes that enable access to and use of these products, specifically by persons with disabilities and older adults (2008a)"* (Cook & Polgar, 2014, p.3). They further describe the use of AT to assist users to overcome infrastructure barriers to enable full societal participation and to accomplish activities safely and easily.

1.4 Differentiating Assistive Technology from Other Technologies

ATs are not simply generic technologies according to Cook and Polgar (2014). Although it seems contestable, they paraphrase Sanford, 2012 (p.55) to identify ATs as: "individualized and usually follows the person." This definition is in contrast to designs that make environments more accessible to individuals with a variety of abilities such as automatic door openers and ramps that stay fixed in a location and are used by many users who come to that particular location. (Cook & Polgar, 2014; p. 4). They propose several principles that should foreground the AT service delivery: (1) the process is person centered, not AT centered, (2) the outcome is enablement of participation in desired activities, (3) an evidence-informed process is used for service delivery, (4) AT service delivery is provided in an ethical manner, and (5) AT services are provided in a sustainable manner. (Cook & Polgar, 2014, p.4).

1.5 The Human Activity Assistive Technology Model (HAAT)

Developed in 1995 by Cook and Hussey, Human Activity Assistive Technology (HAAT) model describes someone (human) doing something (activity) in a context using AT. This simplistic explanation of the HAAT model is deliberately worded to demonstrate where AT fits in the model (Cook & Polgar, 2014). The emphasis of the model is on the person engaged in an activity within chosen environments. Consequently, any application of the model starts with someone doing something in context and then introduces the AT. This order prevents the AT from assuming prime importance with the result that the person adapts to the technology rather than the technology meeting the needs of the person. Therefore, one can argue that this conception of AT renders significant the idea of social roots of disability rather than a bodily impairment due to its emphasis on the person. The model has been used to development of AT, research, and assessment involving the initial selection of AT and ongoing evaluation of the outcome of its use. Figure 1-1 illustrates this model (Cook & Polgar, 2014).

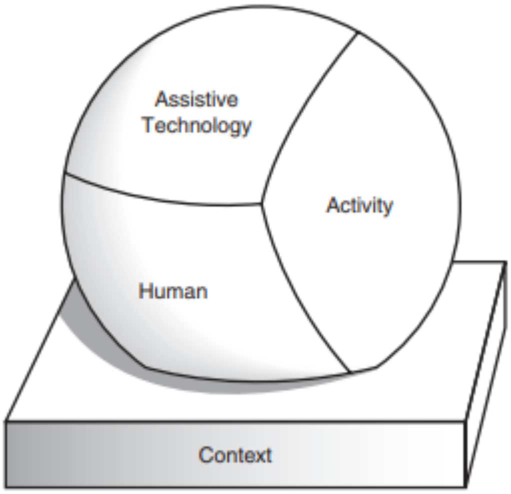


FIGURE 1-1 The Human Activity Assistive Technology model.

Source: (Cook & Polgar, 2014)

Assistive technology in the HAAT model is considered as an enabler for a human doing an activity in context. This component has four aspects: the human/technology interface (HTI), the processor, the environmental interface, and the activity output. Interaction with the human is by the HTI, which forms the boundary between the human and the AT. A two-way interaction occurs at this boundary (i.e., information and forces are directed from the human to the technology and vice versa) (Cook & Polgar, 2014).

The significance of this model is that the context underlying the interaction among the human, technology an activity can be possibly anything from a developing global south rural setting to a more developed and enabled setting. What combines them all is the social barriers that constitute disability. This model then helps us to understand how ATs should be imagined in their application to a disabling experience. From a crude able-bodied conference of solving disabling problems, the HAAT model persuades the policy gurus to focus on the human concerned and see how his/her activity is being constrained by the context – not the bodily impairment – to summon the technologies available to cater to the eliminate the barrier. This approach is therefore privileged when the ICT-led ATs are outlined in the forthcoming pages.

1.6 Defining Information and Communication Technology in a Disability Context

Michailakis (2001) notes the difficulty in precisely defining Information and Communication Technology (ICT) because such technologies change so rapidly in a manner in which the very definitions ought to change as well, due to the drastic changes that occur in the technology itself. However, Michailakis' definition of ICT in a disability context seems to be a more plausible approach given its emphasis on the "Assistive Technology (AT)" side of ICT. This is a crucial point as the use of ICT by the PWD is not revolutionary only due to its accessibility, but also due to its treatment and usage as an AT (Hurulle, Fernando, & Galpaya, 2018). As described below, this is why the emerging ICT-based solutions to social barriers that cause disabling experiences are path-breaking. For Michailakis;

> "The term 'information and communication technology' (ICT) signifies the handling of information with the aid of technical instruments. Handling of information includes computerization and telematics….Telematics signifies the transmission of information, be it speech, text, data or pictures." (Michailakis, 2001, p. 480).

Michailakis' definition is pivotal for this study for several reasons. First, he makes it clear that ICT is nothing but the effective and efficient utilization of information using computerization and telematics. Thus, the revolution created by the ICT-based solutions in the lives of PWD is nothing but the handling of "information" in a creative manner by converting it to an assisitive technology. Therefore, this means that the deprivation of information or inaccessibility to it is one of the fundamental disabling experiences that the PWD face. The enabling process in this sense takes place by creatively handling the information that PWD are deprived of due to vision, hearing, physical or intellectual related impairments; modern computer technology is used to provide that information. Thus, Michailakis (2001) emphasizes the essential role of telematics, which necessitates an efficient transmission process.

However, Michailakis' definition of ICT is limited; thus there is a need for a crucial addition: his definition only encapsulates the computer-dominated ICT and not the contemporary version of mobile phone-dominated ICT. Lazar et al. (2017) point out that the mobile phone is the most important ICT device in the 21st century due to the many advantages resulting from its easy portability and its affordability. Hurulle et al. (2018) note that the relative lower prices of mobile phones and their associated services (such as internet, GPS, etc.), have made them a very popular ICT device, even among the poorest of populations. Therefore, Michailakis' definition of ICT should be extended to incorporate mobile phones as an effective information transmitter. This definition of ICT that includes and greatly emphasizes mobile phones serves as the refence point for this study.

1.7 Classifying Daily Activities and Assistive Technologies

Many research studies on disability that aim to measure the degree of impairment a disabled person experiences, and studies on AT that aim to stipulate appropriate technologies to identified impairments categorize a person's daily activities to different strata in order explore the difficulties faced in varying levels and contexts. For example, the Canadian Longitudinal Study on Aging (CLSA) categorize disability of aged individuals according to the commonly referred strata of "basic activities of daily life (BADL)" and "instrumental activities of daily life (IADL)." According to this classification, BADL refer to the fundamental tasks an independent adult needs to accomplish at a private dwelling, namely; bathing and showering, personal hygiene and grooming (including brushing/combing/styling hair), dressing, toilet hygiene (getting to the toilet, cleaning oneself, and getting back up), functional mobility, often referred to as "transferring", as measured by the ability to walk, get in and out of bed, and get into and out of a chair; the broader definition (moving from one place to another while performing activities) is useful for people with different physical abilities who are still able to get around independently, self-feeding (not including cooking or chewing and swallowing) (Raina, Wolfson, Kirkland, & Griffith, 2018). On the other hand, IADL refer to a fairly advanced set of daily functions from a disability point of view, which include but not limited to, public mobility, preparing meals, managing money, shopping for groceries and other necessities, taking prescribed medications, using a telephone or a mobile phone, religious observances. Moreover, the American Occupational Therapy Association (Roley, DeLany, & Barrows , 2008) lists 12 activities which can be terms as "instrumental" in one's daily life; namely,

a. Care of others (including selecting and supervising caregivers)
b. Care of pets
c. Child rearing
d. Communication management
e. Community mobility
f. Financial management
g. Health management and maintenance
h. Home establishment and maintenance
i. Meal preparation and clean-up
j. Religious observances
k. Safety procedures and emergency responses
l. Shopping

However, there are other broader classifications that are also used in disability research. The WHO International Classification of Functioning, Disability and Health (ICF) is currently the internationally accepted AT classification used world-wide. The Washington Group on Disability Statistics (WG) has simplified the rather rigorous and complicated the WHO classification by categorizing the daily activities of an independent adult to three main criteria: 1) Basic Activity Domains; 2) Body Function Domains; and 3) Complex Activity/Participation Domains. These three macro-categories are then further segmented in the table below.

Table 1: Washington Group Matrix

Domain	Subdomain	Note
Basic Activity		
	Communication	
	Mobility	
	Hearing	
	Visual	
	Cognition/Remembering	
	Upper Body	
	Learning/Understanding	
Body Functions	Affect	Includes aspects of psychological functioning: anxiety and Depression
	Pain	
	Fatigue	
Complex Activity &	Activities of Daily Living (BADL)	E.g. Walking inside the home, standing from a chair, getting Into and out of bed, eating, and dressing
		E.g. Doing chores around the house, preparing meals,

Participa-tion	Instrumental Activities of Daily Living (IADL)	and Managing money
	Getting Along with People (GAP)	Involves interpersonal interactions and relationships (socializing and interacting with others) and includes dealing with family, friends, persons in authority, social media usage
	Major Life Activities (MLA)	Include working inside or outside the home to earn an income and support the family or going to school and achieving Educational goals
	Participation in Society (PS)	Includes joining in community/family gatherings, Religious/civic activities and leisure/social/sports events

Source: (Scientific Foresight Unit (STOA), 2018, p.12-13)

Furthermore, ISO 9999:2011 (2011) classifies assistive products and technologies (including software) for persons with disabilities according to their function. This classification consists of three hierarchical levels in line with the ICF classification.

Table 2: ISO 9999:2011 AT Classification

ISO Code	Description
	Classification
04	Assistive Products for Personal Medical Treatment Included are products intended to improve, monitor or maintain the medical condition of a person. Excluded are assistive products used exclusively by healthcare professionals.

05	Assistive Products for Training in Skills Included are, e.g. devices intended to improve a person’s physical, mental and social abilities. Devices that have a function other than training but that may also be used for training, should be included in the class covering its principal function. Assistive products for vocational assessment and vocational training, see > 28 27.
06	Orthoses and Prostheses Orthoses are externally applied devices used to modify the structural and functional characteristics of the neuro-muscular and skeletal systems; prostheses are externally applied devices used to replace, wholly or in part, an absent or deficient body segment. Included are, e.g. body-powered and externally powered prostheses, which are not part of this International Standard.
09	Assistive Products for Personal Care and Protection Included are, e.g., assistive products for dressing and undressing, for body protection, for personal hygiene, for tracheostomy, ostomy and incontinence care and for sexual activities. Assistive products for eating and drinking, see > 15 09.

Source: (Scientific Foresight Unit (STOA), 2018, p.14)

1.8 Key Methodological Decisions

The principle methodological decision of this report is that the ATs discussed herein are organized firstly according to the activity classification matrix (i.e. BADL and IADL) and only secondly subcategorized according to the nature of ATs (such as haptic aids, travel aids). The main reason for this decision is that following the HAAT model for understanding the interrelationship between the human, context, activity and the AT, the vantage point is set privileging the individual concerned, allowing the technology to follow. Although the European Union (EU) Parliament-summoned technical report on ATs – which provides great inputs to the present report – follows the sequence of the ATs, this report will stick to an organization that follows the human. Inevitably then, due to the fact that the activity classification itself does not completely overlap or correlate with the ATs categorization of ISO 9999:2011, there can be places in this report where it is definitively not clear why a certain AT was included under a particular activity classification banner and not under an alternative one. However, all efforts were taken to correlate the AT with the appropriate activity classification as plausibly as possible.

While acknowledging the versatility of the contemporary activity classifications which are broader and expansive in their current usage, the ATs in this report are organized the under the principal categorization: BADL and IADL. This methodological decision has atleast two main reasons. Firstly, given that the main objective of this report is to list a comprehensive list of ATs available for visual, hearing and physically impaired people and not to provide a conceptual analysis of how assistive technology corresponds with various activity classifications, it seems more logical to ascertain what kind of ATs are available for basic and instrumental activities of the considered disability types in a clearer way. Secondly, this decision helps to avoid any effort to forcefully coincide the ATs over the activity classifications since it is easier to differentiate between BADL and IADL rather than the aforementioned with 'major activities', 'participation in society' and 'getting along with people.' In support to this decision the CLSA also had used the two principal classifications – BADL and IADL – for their interim report (Raina, Wolfson, Kirkland, & Griffith, 2018).

In terms of the organization of this report, the chapters are divided according to the type of disability, while the main branches of the available ATs for each disability type is introduced in each chapter. The sub-categories of each type of AT is only discussed under BADL or IADL according to the nature of assistance that they aim to provide. For instance, haptic aids are introduced under visual impairments as a type of AT and its sub-categories such as advanced canes, advanced Braille applications are described under BADL or IADL depending on the nature of their assistive task corresponding with the activity matrix.

Fifth chapter covers "major activities of life" – limited to education, financial and health inclusion. The sixth chapter on emerging technologies describe how digital technologies continue to broaden the horizons of available ATs for each type of disability.

1.9 Limitations of the Study

The ATs listed in this report pertain to only three types of disabilities. Further, the category "physical impairments" itself is found to be ambiguous in nature in view of pooling in all the possible ATs as enablers. Importantly, the existence of a vast number of sources carrying the information about ICT based ATs, mostly available online and in closed-access books, make it relatively difficult to prepare an exhaustive list of the available ATs for a particular type of disability. Moreover, technologies keep advancing every day and they are not consistently being updated in the standard communication channels such as web sites and open-access books. Therefore, this report does not claim to contain exhaustive lists of ATs available for a particular type of disability. On the other hand, ATs listed under “major activities of life” are limited to education, financial and health inclusion topics.

2. VISUAL IMPAIRMENTS

2.1 Introduction

A European Union-summoned technical report on the ATs for PWD (Scientific Foresight Unit (STOA), 2018) views the existing ATs concerning visual impairments to be falling within five functional categories, namely;

i. haptic aids,
ii. travelling aids,
iii. AT for accessible information and communication,
iv. AT for daily living, and
v. phone and tablet applications.

These categories may not cleanly fit on to the present report's activity classification matrix – the WG adaptation. For example, haptic aids can overlap on BADL and IADL, or even on other activity categories.

i. Haptic Aids

Haptic aids pertain to senses of touch and tactile activities. As Hersh et al. (2008) correctly emphasize, haptic aids do not merely replace the impaired eyes with the able hands, rather they refer to a whole array of tactile capabilities of the humans, not to mention the value of feet for that matter, for the visually impaired people. Hence, many of those aids are non-ICT based ATs although there is an entire array if emerging technologies in the domain. In fact, the most of the advanced haptic aids (mentioned below) contain ICT add-on's that make them more appealing to the users. Haptic low-tech aids include the white cane, the traditional Braille system and embossed pictures (including tactile maps), while technologically advanced applications include (Hersh, Johnson, & Keating, 2008; Scientific Foresight Unit (STOA), 2018);

a. advanced Braille applications,
b. advanced canes,
c. haptic aids for computer usage and
d. matrices of point stimuli.

ii. Travelling Aids

It is seen that a vast majority of the ATs available for the visually impaired people are concerned with travelling aids. It may perhaps be because as Hersh et al. (2008) observe that many of the existing urban environments were never made with a cognizance of what kind of difficulties could a person with a disability would face in such environments. Further to the observation by Hersh et al., one can see how the rural environments - where according to the

UN reports, the largest proportion of the PWD live in the world - are not even imagined herein, highlighting the depth of their public space barriers. Admitting this limitation of Hersh et al.'s conception of environmental inaccessibility, we outline below nonetheless a noteworthy list of tasks that a visually impaired person might experience as difficult to accomplish:

a. Being able to avoid obstacles on the pavement.
b. Walking in the right direction.
c. Crossing the road safely.
d. Finding the correct bus stop.
e. Knowing which is the right bus.
f. Paying the correct fare.
g. Finding a vacant seat.
h. Knowing when to get off the bus.
i. Crossing the road safely (at a different location and probably using a different type of crossing).
j. Walking to the hospital entrance.
k. Finding the main reception desk.
l. Finding and using a lift (elevator) to the correct floor.
m. Locating the waiting room and the consultant's room.
n. Leaving the hospital and repeating the travel process in reverse to return home.

The above list helps to schematize the nature of a travel activity of a visually impaired person – whether it is a BADL or a IADL - which then helps to identify the avenues where the AT can contribute, in light of the HAAT model.

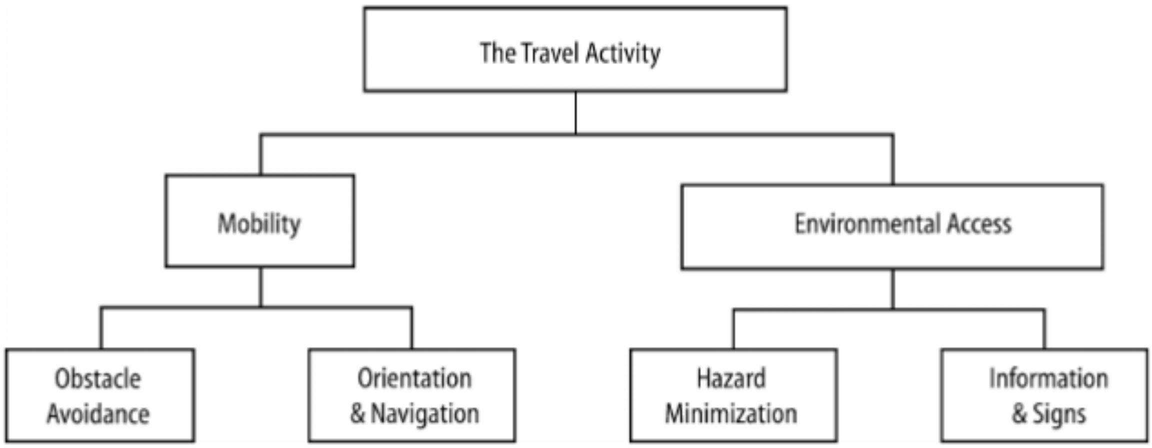


Figure 1: Tasks within the Travel Activity

Source: (Hersh, Johnson, & Keating, 2008, p.169)

As it can be seen from figure 1, there are two ‘contexts’ – in light of the HAAT model - to reduce barriers pertaining to travelling: first, concerning mobility and the second, concerning environmental access. Consequently, the corresponding ATs to the two contexts should perform different enabling fucntions.

The EU report views travelling challenges of a visually impaired person as those concerning; 1) mobility, 2) navigation and 3) environmental access (Scientific Foresight Unit (STOA), 2018), according to which;

a. Mobility concerns the identification of a safe path avoiding and negotiating obstacles and hazards.
b. Navigation concerns wayfinding, that is to say, knowing the current location and establishing how to get from the current location to a destination.
c. Environmental access concerns good design of the physical environment in order to minimize hazards for blind and visually impaired people and to provide them with contextual information.

Hence, the corresponding ATs are also organized according to these categories. Some mobility ATs that help a person to walk within one’s house are not outlined in this report for the reason that they are mostly nit ICT-led devices. They may well be conceived under BADL. Public mobility ATs are outlined under IADL. Same principle applies to navigation and environment access ATs given that many emerging ATs exist that cater to domestic navigation and environment access needs (e.g. ambient living, etc.).

Cercone et al. (2013, p.4) list out the main requirements for an Electronic Travel Aid (ETA):

a. Detection of obstacles in the travel path from ground level to head height for the full body width.
b. Travel surface information including textures and discontinuities.
c. Detection of objects bordering the travel path for shore-lining and projection.
d. Distant object and cardinal direction information for projection of a straight line.
e. Landmark location and identification information.
f. Information enabling self-familiarization and mental mapping of an environment.

Although ETA’s will not formally count as ICT aided ATs, it is helpful to recognize these requirements as also quite applicable to ICT aided ATs. In many an occasion, several of the above requirements are provided by ICT add on’s to the already existing devices. Understandably, Cercone et al. (2013) observe that it is highly unlikely that on AT device would encompass all of the above requirements, hence warranting us to appreciate the technology based on its applicable context.

iii. Technology for Accessible Information and Communication

Technology for accessible information and communication includes technologies for specific purposes, such as education, working and employment, leisure and recreation. They comprise accessibility tools for television, computer, Internet navigation and mobile phone communication (Hersh, Johnson, & Keating, 2008). A clear distinction should be drawn between low vision aids and systems tailored to the needs of blind people. Low vision aids aim at maximizing the remaining sight by;

a. increasing the object size, e.g. larger print keyboard stickers,
b. decreasing the viewing distance, e.g. magnifiers of various types, spectacles etc.,
c. video magnification, e.g. closed-circuit television (CCTV), computer operating systems provided with magnification accessibility features,
d. telescopic magnification, e.g. contact lens telescopes.

These tools are applied to different devices, such as computers, screens, tablets and phones etc. Systems tailored to the needs of blind people turn visual information into other sensory modalities.

iv. AT for Daily Living

Arguably, AT for daily living are a category of ATs that can be exclusively categorized under BADL. As also mapped out in figure 2, these ATs specifically aim to address the large number of basic daily tasks that visually impaired people must accomplish to be living independently. Most of the tasks mapped out in figure 2 are performed inside one's homes although it is not always true. There are a wide range of products servicing these needs while many have adopted various ICTs to improve their effectiveness. Seemingly, money, finance and shopping are not BADL although Hersh et al. include them into this list.

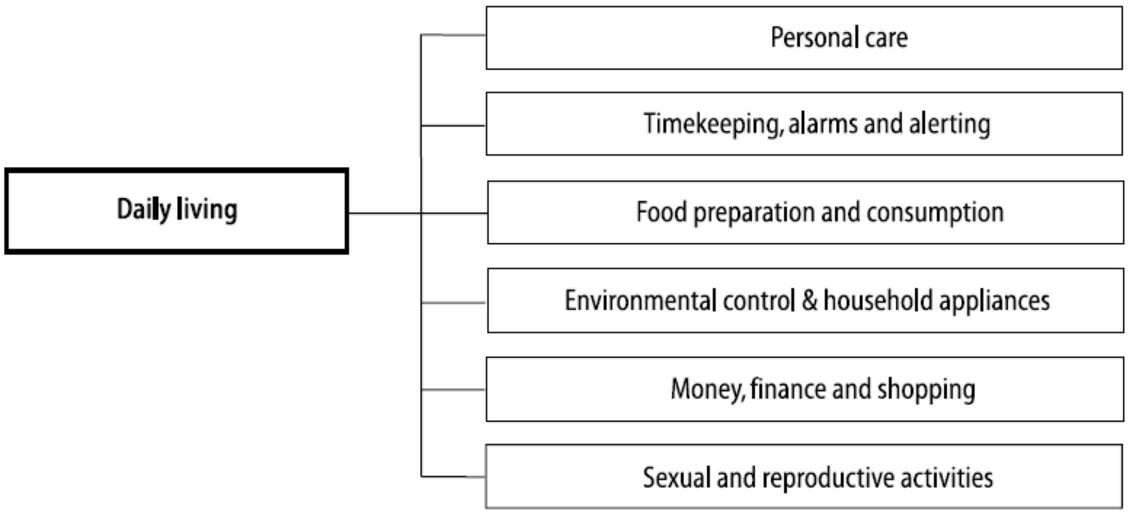


Figure 2: ATs for Daily Living Categorization
Source: Hersh et al. (2008, p.617)

From figure 2, money, finance and shopping is covered as a separate topic in chapter 5. Environmental control and household appliances where applicable overlap under other categories. Rest of the categories seem to be non-ICT based devices and are therefore largely not discussed in this report.

v. Phone and Tablet Applications for Visually Impaired People

Phone and tablet applications are the final category of ATs that can be listed under BADL. However, most of such apps are inevitably listed under IADL given their complexity of task accomplishment. Many assist in instrumental tasks. Nonetheless, there are other apps that predominantly could assist the visually impaired people in their daily living, inside their homes.

Table 3: Summary of Types of Aids for Visual Impairments and corresponding Types of Activities

Type of Aid	Sub-Categories	Type of Activity ascribed to in this report	Example ATs
Haptic Aids	Low Tech Haptic Aids	Mostly non-ICT based solutions and are not considered in this report	Traditional Braille Systems
	Advanced Braille Applications	IADL	Braille Note Takers, Computers

	Advanced Canes	BADL	Smart Canes
	Haptic Aids for Computer Usage	IADL	Haptic Displays
	Matrices of Point Stimuli	Overlaps with other ATs	
Travelling Aids	Low-tech Primary Aids	Mostly non-ICT based solutions and are not considered in this report	White Cane
	High-tech Primary Aids	IADL	Ultra Cane
	Secondary Aids: Electronic Travel Devices (ETDs)	IADL	Braille Compass
	Secondary Aids: Mobile Phone Tech-nology	IADL	GPS Systems
Embedded Tech-nologies		IADL	
AT for Accessible Information and Communication	Low Visions Aids	BADL	
	Systems Tailored to the Needs of Blind People	IADL	
AT for Daily Living		Mostly non-ICT based solutions and are not considered in this report	
Phone and Tablet Applications		BADL and IADL	

2.2 Basic Activities of Daily Life

As pointed out before, BADL refer to those most primary activities that a person needs to accomplish in their day-today chores such as getting in and out of the bed and eating one's own food. In context of the visually impaired people, functional mobility inside one's home avoiding its numerous obstacles is a key function that require AT. In light of this, many low-tech haptic aids suffice to the aforementioned task which nonetheless is beyond the ambit of this report which focuses on ICT-led technologies. However, there are other advanced canes such as smart canes which also perform the task of mobility inside the home. Advanced cans may not only be used for outside travelling purposes. In a context where most of the houses are not constructed with accessibility in mind, a smart cane undoubtedly can assist the visually impaired people. While low-tech methods like good lighting, well-designed houses, tactile alarms, etc. are formidable embedded technologies that can assist the visually impaired people, their mostly non-ICT nature prevents them being listed and discussed under BADL.

i. Advanced canes

The EU report emphasizes that advanced canes are one type of AT that have evolved and developed drastically over the last decades. Cane technology has chiefly focused on improving lightness and length of canes, consequently most progress has been made in relation to the material used (e.g. graphite-reinforced plastic, fibre- reinforced plastic etc.). This technology is premised on traditional cane principles coupled with additional technology to detect obstacles and transmit information to the cane bearer (Hersh, Johnson, & Keating, 2008). Technologies explored to detect obstacles include laser and ultrasounds. Technologies to transmit information include both audio and tactile interfaces as well as a combination of the two. The tactile interface is usually made of vibrating buttons or pins. The audio interface usually comprises tones of different pitch conveyed through a single earphone. Information includes basic details on obstacles, but can also become very sophisticated, using a combination of haptic and auditory signals to suggest a spatial map of the surroundings (Scientific Foresight Unit (STOA), 2018).

To discuss a bit more about a three specific types of advanced canes, K-Sonar Cane and mini-radar are ultrasound-based sonar, which can detect the distance to the obstacle and provide sound and/or audio messages to the user; a microprocessor converts the distance to the obstacle into sound that the user can hear through earphones (Estrada, 2016). The Ultracane is a cane with embedded ultrasonic range scanners that, if an obstacle is detected, provides a vibro-tactile warning to the user. Laser Cane on the other hand is a cane using three laser range sensors exploring the volume in front of the user and an audio system producing warning sounds and/or vibrations (Estrada, 2016). For example, figure 3 illustrates how an electromagnetic (EM) system mounted on to a cane helps to avoid obstacles.

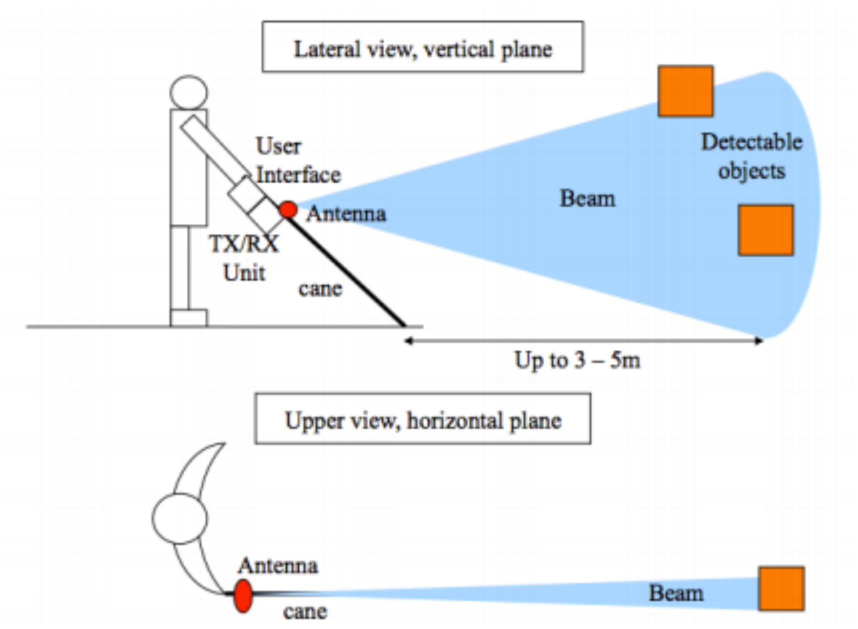


Figure 3: Example of the miniaturized EM system mounted on a cane (lateral and top views)
Source: (Estrada, 2016)

ii. Low Vision Aids for Accessible Information and Communication

Advanced canes are not the only ATs that can be categorized under BADL. Low vision aids, a sub-category of AT for accessible information are according to Hersh et al. (2008) mostly overlooked technologies which otherwise would assist the visually impaired people immensely. As the name itself suggests, "low vision aids" aim to maximize the remaining sight according to the Scientific Foresight Unit report of the European Parliament (2018) by;

a. increasing the object size, e.g. larger print keyboard stickers,
b. decreasing the viewing distance, e.g. magnifiers of various types, spectacles etc.,
c. video magnification, e.g. closed-circuit television (CCTV), computer operating systems provided with magnification accessibility features,
d. telescopic magnification, e.g. contact lens telescopes.

Figure 4 presents the various methods to maximize the current level of sight and their few examples of corresponding ATs available in the market. For the purpose of this report, only real image or transverse magnification devices are listed since most of the other ATs are non-ICT based ones.

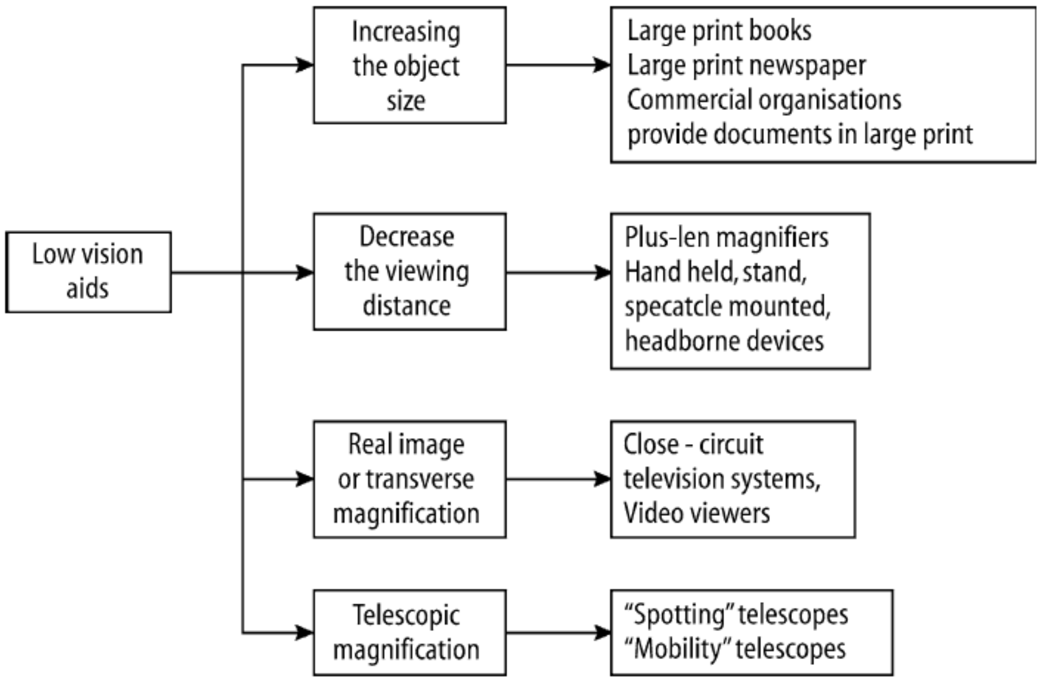


Figure 4: Low Vision Aids Categorization
Source: Hersh et al. (2008, p.392)

iii. Phone and Tablet Applications for Basic Activities

Phone and tablet applications are the final category of ATs that can be listed under BADL. However, most of such apps are inevitably listed under IADL given their complexity of task accomplishment. Many assist in instrumental tasks. Nonetheless, there are other apps that predominantly could assist the visually impaired people in their daily living, inside their homes. For this reason, such apps must be considered as those assisting BADL. Phone and tablet apps that can be considered to be aiding BADL are;

a. magnification apps, which use the phone camera as a magnifying glass;
b. colour detection apps, which use the camera to identify and speak the name of the colour of an item;
c. object identification apps, which use the camera to identify objects, also by reading labels and barcodes;
d. light identification apps, which convert light levels or motion into audio tones;
e. voice recognition apps, such as Siri on iOS.

2.3 Instrumental Activities of Daily Life

While the idea of IADL is much more ambiguous and contestable than BADL, it nonetheless provides a helpful avenue to pool in the AT efforts catering the PWD in a more meaningful way as this activity distinction allows the AT to follow the "human activity." Hence, we are able to distinguish between primary (BADL) and secondary (IADL) areas of daily life the people impaired with different types of disabilities – in our case visual, hearing and motor – need assistance with using the technologies available. Consequently, we are able to identify the relative importance of any AT both available and emerging by perusing about to what type of daily activity does the concerned AT assists the person with. This reaffirms the concept of HAAT model of ATs.

i. Advanced Braille Applications

Firstly, advanced Braille applications are technological applications that are mostly used to simplify the use of Braille. The main means how the emerging technologies have dealt with the issue of simplifying the rather cumbersome traditional Braille systems is by mostly digitizing them. Hence, there are atleast four types of advanced Braille applications (Scientific Foresight Unit (STOA), 2018); namely,

a. Software for Braille training,
b. Braille embossers (also known as Braille printers) which transfer computer-generated text into embossed Braille output,
c. Braille translation programs, which convert text scanned in or generated via standard word processing programs into Braille,
d. Braille computer interfaces, such as Braille monitors and keyboards.

As the above categorization shows, many of the advanced Braille applications involve computer and mobile technologies and hence will be considered to assist in daily instrumental tasks.

ii. Haptic Aids for Computer Use

On the other hand, there also haptic aids that aid computer use. By virtue of the fact that computer usage is considered to be an instrumental activity, atleast as of now until it becomes more part and parcel of basic daily tasks, haptic aids for computer use are recognized to be aiding IADL. Moreover, computer use for visually impaired people, as corroborated by multiple studies, is a complex task. In light if this, these haptic aids strive to make the blind or sight-hampered user experience more accessible and ultimately enriching. Haptic aids for computer use include (Scientific Foresight Unit (STOA), 2018);

a. Tactile computer mouse and touchpad,

b. Haptic graphical user interface,

c. Haptic display.

iii. Matrices of Point Stimuli

Matrices of point stimuli is a major enabling technology for new haptic applications (Scientific Foresight Unit (STOA), 2018). Haptic applications mostly convey their signals to the user's body surface. By using several static and vibrating pins, it is possible to create a matrix of point stimuli. By vigorously activating some of these pins, it is possible to form different patterns which can provide details that are usually only captured by sighted people, such as written texts, tactile pictures (including diagrams and maps), etc. However, since that many of the ATs involved in this category overlap with ATs discussed elsewhere, a separate list of such ATs are not listed in the executive list in section 2.4 below.

iv. Primary Aids for Travelling

Except for the low-tech primary travelling aids, rest all of the travelling aids, due to their applicability only in outside the household spaces must be considered as ATs that assist IADL. Primary aids (for travelling) are those devices that are mainly used in near space. This is the reason why they are most assistive inside one's homes, although they may also perform important outside-home assistive tasks. Given how mobility is a paramount function that the visually impaired people must triumph every day, primary travelling aids generally are much popular among the community than other ATs. The European Parliament report aptly states how these aids "must be easy to carry, small, lightweight and, ideally, consist of a single unit. Moreover, given that they can be used outdoor and in many different situations, it is paramount that they are robust, able to withstand all weather conditions as well as knocks and falls" (Scientific Foresight Unit (STOA), 2018, p.29).

Among the primary aids, white cane, a low-tech primary aid is the most commonly used traveelin aid. Since these low-tech aids are mostly non ICT based in nature, they are not listed in this report. High-tech primary aids (travelling aids) on the other hand, consist of ICT based applications which include various obstacle and object location detectors that scan the environment. They employ various laser and ultra rays technologies to perform these tasks. For the purpose of this report they include ultra canes and ultra bikes.

v. Secondary Aids for Travelling

Secondary aids (travelling aids) are primarily used in far space for orientation and navigation. These devices generally aim to provide two types of information (Scientific Foresight Unit (STOA), 2018); namely,

a. provide geo-location information,
b. provide landmark information.

The first type is about assistance provided to reach a selected destination and find the best the route to be followed. In view of this, Global Positioning System (GPS) and its many applications guide the user towards his/her destination with explicit directions. Landmark details serve a number of purposes: they allow validating positioning information, enabling a user to continue following a planned route even if satellite signals are temporarily unavailable (Scientific Foresight Unit (STOA), 2018). They also allow finding specific points along the route, such as an entrance, an obstacle, etc. Understandably then, the most commonly used type of secondary travel aid by the visually impaired people is the GPS system combined with geographical information systems (GIS).

Secondary aids consist of more popular electronic travel devices (ETDs) consisting of several hardware components specifically designed to assist the disabled person, and assistive applications in mobile phone technology. ETDs are usually wearable devices including a small computer (provided with dedicated software for information processing, often with speech and voice recognition) coupled with GPS and GIS systems (Scientific Foresight Unit (STOA), 2018). They can also include a Braille compass (a directional device using Braille characters). Early ETDs provided information mainly via speech audio outputs. Today, audio signals (non-speech) and haptic outputs are also commonly used.

Another approach, and the second type of secondary travelling aids which are becoming increasingly important, is based on the development of assistive applications to be used in standard mobile phone technology (Hersh, Johnson, & Keating, 2008). Smart mobile phones include components such as a multi-megapixel camera, high-quality directional microphone, tri-axial accelerometer, GPS receiver, digital voice recorder, touch-screen, electronic temperature chip, several vibration units, magnetic and electric field sensors as well as 4G, Wi-Fi and Bluetooth communications. Through low-cost downloadable applications, all these technologies can also be used for assistive purposes. There are many obvious advantages of such a strategy, inter alia the increased portability, lower costs and increased user acceptance (Scientific Foresight Unit

(STOA), 2018). Moreover, by using different communication tools, mobile phones allow overcoming the main GPS limitation: the limited capacity for indoor operation. Therefore, mobile phones are not only useful as assistive devices in one's instrumental daily activities, rather they are more capable of assisting a disabled person inside one's homes, and hence for BADL. Figure 5 shows some of the advantages and disadvantages of three main GPS ATs used by visually impaired people.

BrailleNote GPS	PDA	Improved upon the powerful software features found in GPS-Talk; no route length limitation; full access to the maps with or without GPS; fully accessible PDA with Internet access, email capabilities, word processing, address book, mp3 player, *etc.*	Compatible only with specific Windows CE device – the BrailleNote or VoiceNote
Trekker	PDA	Stand-alone GPS unit; small package and light weight; provides street, point of interest, and directional information; uses voice recording to name points of interest	Routes limited to one map section
StreetTalk	PDA	Works with the PacMate PDA; is an inexpensive software addition to the PacMate	Software is adapted from a GPS program for sighted people and not all functions are accessible; does not allow for input of personalized points of interest or routes

Figure 5: Advantages and Disadvantages of BarilleNote GPS, Trekker and StreetTalk
Source: Hersh et al. (2008)

vi. High-tech Embedded Technologies

Whether high-tech or low-tech, embedded technologies are environmental accessibility tools. They aim to transform the outside environment instead of providing an AT to the user. High-tech embedded technology devices are electronic signal systems embedded in the environment which are activated by the presence of the disabled person (Hersh, Johnson, & Keating, 2008). Talking signs are repeating, directionally selective voice messages transmitted by infrared light to a hand-held receiver. Radio frequency identification (RFID) tags are also used to broadcast signals to be transmitted to the user either as an audio signal over a headphone or by vibration. Similarly, Bluetooth technology is used to create signal systems and alarms (Hersh, Johnson, & Keating, 2008). Ultimately, embedded technologies also aim to make the mobility of the visually impaired user more hassle-free. Although discussed as essentially IADL ATs, these in the long term can significantly boost the home experiences of the users as well. Figure 6 maps out the avenues in which the embedded technologies assist the visually impaired user.

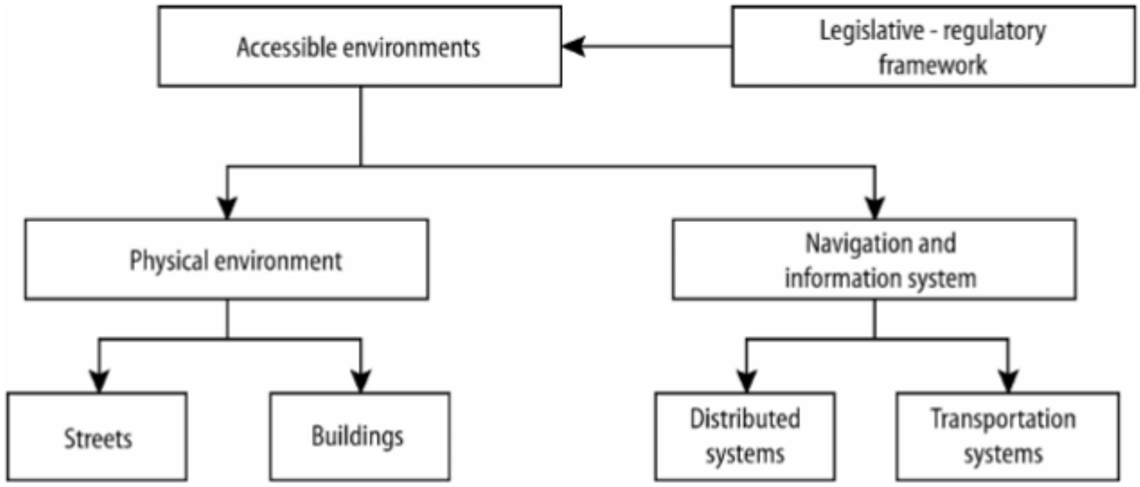


Figure 6: Embedded Technologies Categorization
Source: Hersh (2008, p.326)

Talking Signs(R) Remote Infrared Audible Signage (RIAS) technology for example, an extremely important high-tech embedded technology, is designed to substitute for missing visual cues for those with limited or no sight (Department of Geography at the University of California at Santa Barbara, n.d.). A transmitter continuously emits an infrared beam that can be picked up with a small hand-held receiver. The user scans the environment with the receiver and intercepts the infrared beam which contains a human- voice informational message that is heard through the receiver's speaker. In this way, a blind person can learn about what is in the environment and the direction to that location, much as signs and vision allow for other people (see figures 7 to 12 for illustrations about how *Talking Signs* operate: source (Department of Geography at the University of California at Santa Barbara, n.d.)).

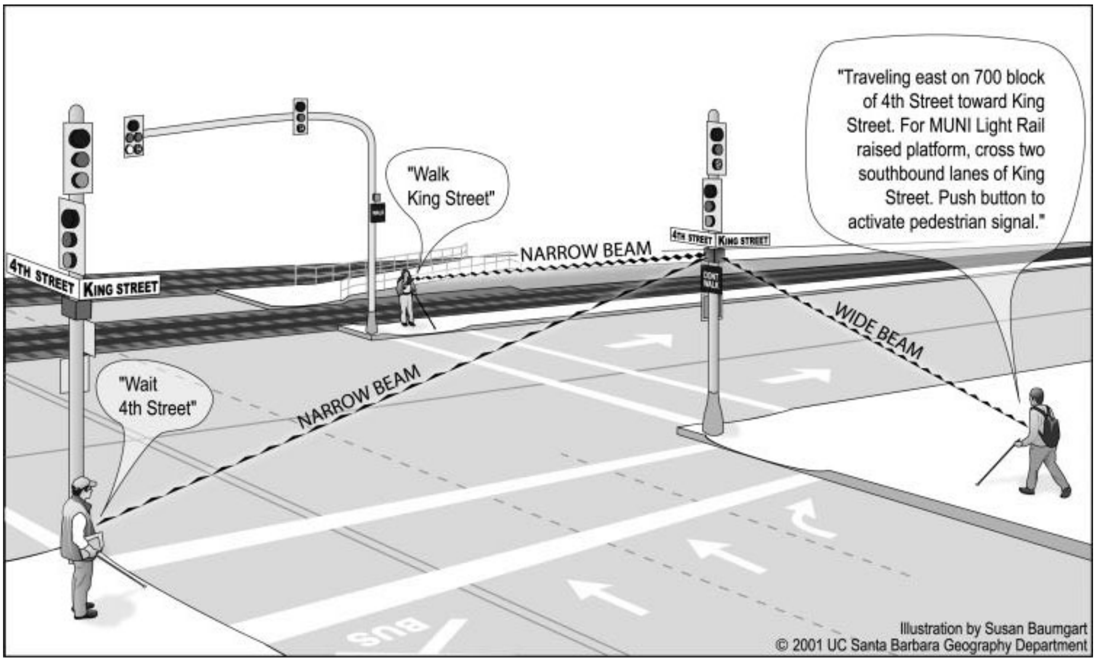


Figure 7: *Street Crossing / Oblique - Talking Signs*

Figure 8: *Outside Building Transmitter - Talking Signs*

Figure 9: *Interior Transmitter Cover - Talking Signs*

Figure 10: *Talking Signs Receiver - Talking Signs*

Figure 11: *Bus Equipped with Talking Signs Transmitter - Talking Signs*

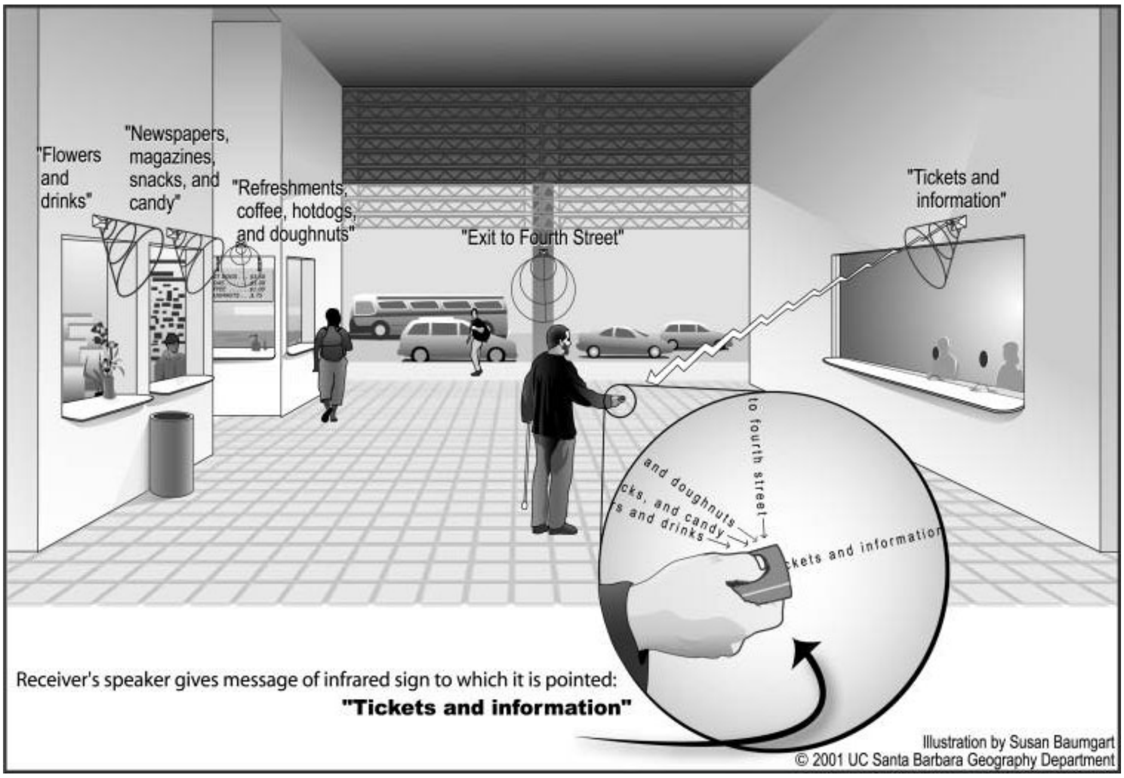


Figure 12: *Partial Interior of Caltrain Station - Talking Signs*

vii. Systems Tailored to the needs of Blind People for Accessible Information and Communication

Systems tailored the needs of blind people as mapped out in figure 13, turn visual information into other sensory modalities, they are based on speech, text and Braille conversion technologies (e.g. Braille printers, Braille keyboards, Braille text recognition software etc.), text and screen readers (including audio-books and alike), voice recognition software (e.g. voice command for mobile phones). Specific applications include;

a. audio support software,

b. text-to-speech software,

c. portable reading devices,

d. Braille computer input and output hardware and software,

e. tactile images and screens,

f. audio operating systems for computers (Hersh, Johnson, & Keating, 2008). They mostly use haptic or audio technologies, or a combination of both.

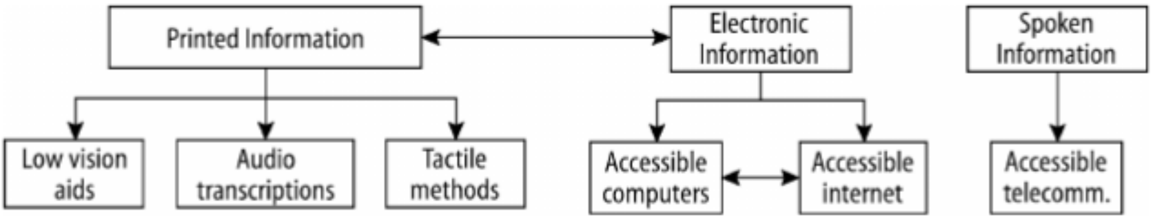


Figure 13: Technology for Accessible Information and Communication Categorization

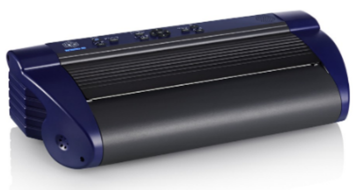
Source: Hersh et al. (2008, p. 387)

viii. Phone and Tablet Applications for Instrumental Activities

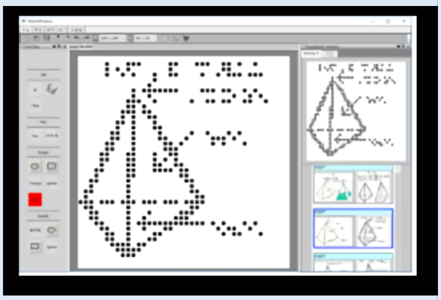
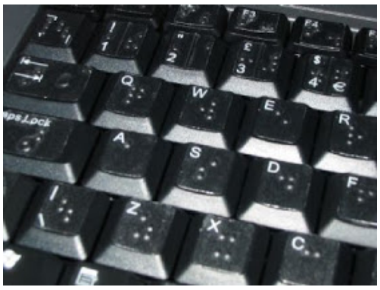
In section iii of 2.2, we outlined a few types of phone and tablet apps that can be considered to be aiding BADL. Yet, there are a range of other apps that assist to perform more complex tasks and therefore which should be considered as aiding IADL. They are;

a. money identification apps, which use the camera to identify the value of a note;
b. crowdsourcing apps, which circulate photos taken by disabled persons among anonymous web volunteers who describe what they see;
c. scan and read apps, which turn images of text into plain text and read it;
d. screen reading apps, which are standard screen readers;
e. location and GPS apps, some of them specifically tailored to the needs of blind people;
f. reading apps, for reading e-books;
g. Braille apps, which teach Braille and allow typing Braille on the touchscreen;
h. security apps, which connect blind users to sighted volunteers they can video chat with: the sighted person can tell the blind person what he sees when the blind user points his phone's camera at something.

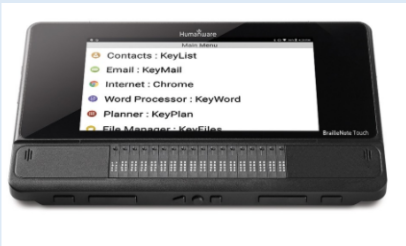
2.4 List of ICT based ATs for Visual Impairments

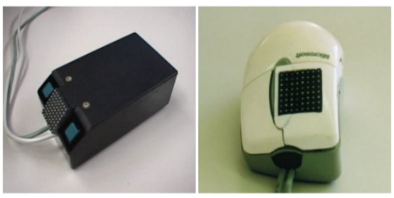
Product	Origin	Price	Availability		Description of AT
			Amazon.com	Amazon.in	
Haptic Aids: Advanced Braille Applications (Use: IADL)					
Online Braille Training: UEB Online *https://uebonline.org/about/Braille/*	Australia	Free	N/A	N/A	Software for Braille Training
Online Braille Training: BRL: Braille Through Remote Learning *http://www.brl.org/*	USA	Free	N/A	N/A	Software for Braille Training
Index Basic-D V5 Embosser 	UK	GBP 2,450	No	No	Braille Embossers/Printers to print documents on Braille paper
Romeo 60 single-sided Braille embosser 	UK	GBP 2,250	No	No	Braille Embossers/Printers to print documents on Braille paper
Juliet 120 double-sided Braille embosser 	UK	GBP 2,750	No	No	Braille Embossers/Printers to print documents on Braille paper

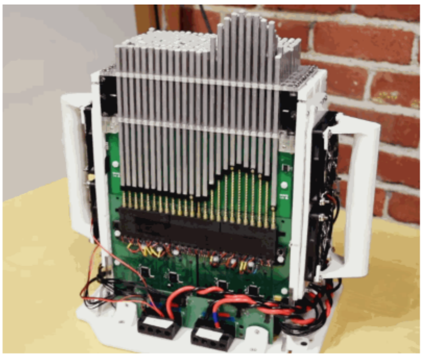
Index Everest-D V5 Embosser 	UK	GBP 3,150	No	No	Braille Embossers/Printers to print documents on Braille paper
FanFold-D V5 	UK	GBP 12,995	No	No	Braille Embossers/Printers to print documents on Braille paper
Index-direct-Braille *https://www.indexBraille.com/en-us/support/Braille-editors/index-direct-Braille*	Sweden	Free	N/A	N/A	Braille Translation Program to convert text scanned in or generated via standard word processing programs to Braille
DBT Duxbury US *https://www.indexBraille.com/en-us/support/Braille-editors/dbt-duxbury-us*	Sweden	Free	N/A	N/A	Braille Translation Program to convert text scanned in or generated via standard word processing programs to Braille
BrailleBlaster *https://www.perkinselearning.org/technology/posts/Brailleblaster-free-Braille-transcription-software*	USA	Free	N/A	N/A	https://www.perkinselearning.org/technology/posts/Brailleblaster-free-Braille-transcription-software

Braille Contents Author *http://www.powerct.kr/* 	South Korea	Una-vaila-ble	No	No	Braille Translation Program to convert text scanned in or generated via standard word processing programs to Braille
Braille Keyboard 		USD 65	Yes	Yes	Braille Keyboards (keyboards with Braille embossed)
Braille Overlay for Keyboards		USD 20	Yes	Yes	Braille Keyboards
Brailliant[1] BI14 Braille display 	UK	GBP 845	Yes	No	Braille Computer Interfaces that display information in Braille format
Brailliant BI 40 (NEW generation) Braille display	UK	GBP 2,475	Yes	No	Braille Computer Interfaces that display information in Braille format

[1] Brailliant is a brand produced by the UK-based company Humanware which are commonly available for purchase in Amazon.com.

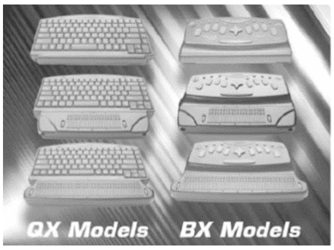
					
Brailliant BI 80 (NEW generation) Braille display 	UK	GBP 7,235	Yes	No	Braille Computer Interfaces that display information in Braille format
Braille Note Taker 	UK	GBP 3,600	Yes	No	Braille Computer Interfaces that display information in Braille format
ElBraille 14 Notetaker 	India	Unavailable	No	No	Braille Computer Interfaces
Haptic Aids: Advanced Canes (Use: BADL)					
K-Sonar Cane 	New Zealand	USD 710	No	No	

WeWALK Smart Cane 	UK	USD 499	Yes	No	
WPQW Cane Smart Cane		USD 161	Yes	No	
MCP Jindal Smart Walking Stick with Fm Radio, Siren & Torch 	India	INR 1699	No	Yes	
Haptic Aids for Computer Use (Use: IADL)					
Tactile Mouse  Tactile Mouse Version 1 (left) and Version 2 (right).  Tactile Mouse Version 3 (left) and Version 4 (right).	Japan	Una-vaila-ble	No	No	

TouchPad Pro **https://www.touchpadpro.org/** 	USA	Una-vaila-ble	No	No	
Tactile Pro Braille Tablet 	South Korea	Una-vaila-ble	No	No	
2.5D Display 	USA	Not in the mar-ket yet	N/A	N/A	
Travelling Aids: High-tech Primary Aids (Use: BADL & IADL)					
Ultra Cane (Batcane) **https://www.ultracane.com/ultra-canecat**	UK	GBP 590	No	No	

					
Ultra Bike 	UK	Not for sale yet	N/A	N/A	
Travelling Aids: Electronic Travel Aids (Use: IADL)					
Braille Note GPS Products: (Sendero)  	USA	Una-vaila-ble	No	No	GPS devices where guidance is generated in Braille format

Trekker **https://www.afb.org/aw/4/4/14834** 	USA	USD 1595	No	No	GPS device with audio output guidance
Victor Reader Trek – talking book player & GPS 	UK	GBP 545 / USD 639	Yes	No	GPS device with audio output guidance
PAC Mate Omni GPS; and StreetTalk VIP GPS **https://support.freedomscientific.com/About/News/Article/72**	USA	Unavailable	No	No	
AT for Accessible Information and Communication: Low Vision Aids (Use: IADL)					
Digital Magnifier	UK	USD 150-USD 3,000	Yes	No	Magnifiers

					
AT for Accessible Information and Communication: Systems Tailored to the Need of Visually Impaired People (Use: IADL)					
Braille Portable Computers 	USA	Una-vaila-ble	No	No	Braille Computers
Open Book 	USA	Una-vaila-ble	No	No	Audio Support Software
Portable Reading Solution 	USA	Una-vaila-ble	No	No	Text to Speech Software

Product	Price	Ratings (App Store/Google Play)	Compatibility
Phone and tablet applications for blind and visually impaired people: Magnification Apps[2] (Use: BADL)			
Lumin	USD0.99	3.5	Requires iOS 7.0 or later. Compatible with iPhone, iPad, and iPod touch.
SuperVision+ Magnifier	Free	3.9	Requires iOS 8.0 or later. Compatible with iPhone, iPad, and iPod touch.
Magnifier – Built into the iPhone and the iPad	Free		
KNFB Reader	USD99.99.		Requires Android 4.3 and up
MagLight+ Magnifying Glass with Light	USD0.99	3.7	Requires iOS 10.0 or later. Compatible with iPhone,

[2] There are a large number of magnification apps available both on App Store and Google Play. The apps listed here are therefore not exhaustive but are representative of the range.

			iPad, and iPod touch.
Magnificent	Free	3.9	Requires Android 4.0 and up
See It - Video Magnifier	USD19.99	None	Requires Android 4.0.3 and up
Phone and tablet applications for Visually Impaired People: Magnification Apps (Use: BADL)			
Color Grab	Free	4.4	Requires Android 2.3 and up
Swatches	Free	4.5	Requires iOS 10.0 or later. Compati-ble with iPhone, iPad, and iPod touch.

Examine clothes color	Free	4.7	Requires iOS 7.0 or later. Compatible with iPhone, iPad, and iPod touch.
Color meter Free- Live colors	Free	4.3	Requires Android 2.2 and up
Image color identifier	Unavailable	3.9	Requires Android 4.0.3 and up (by Indian developer Ashish Polai)
Phone and tablet applications for Visually Impaired People: Money Identification Apps (Use: IADL)			
MCT Money Reader	Free	3.5	Requires iOS 10.0 or later. Compatible with iPhone, iPad, and iPod touch.
Cash Reader: Bill Identifier	Free	4.4	Requires iOS 11.0 or later. Compatible with iPhone, iPad, and iPod touch.

	Full version for Lifetime is USD17.99		
Myanmar Money Reader	Unavailable	5.0	Requires Android 4.4 and up (Offered By Myanmar Assistive Technology Team)
(मणि) MANI	Free	5.0	Requires iOS 9.0 or later. Compatible with iPhone, iPad, and iPod touch. (Offered by Reserve Bank of India)
Phone and tablet applications for Visually Impaired People: Object Identification Apps (Use: BADL)			
Toolwiz Eyes	USD7.99	Unavailable	Unavailable
VIP Code Reader	Free	4.3	Requires Android 4.4 and up

Envision ELI	Free	3.0	Requires iOS 8.0 or later. Compatible with iPhone, iPad, and iPod touch.
LookTel Recognizer	USD9.99.		Available now for iOS devices running iOS 5.0 and higher
TapTapSee	Free	4.2	Requires iOS 10.0 or later. Compatible with iPhone, iPad, and iPod touch.
Phone and tablet applications for Visually Impaired People: Crowd Sourcing Apps (Use: IADL)			
Blindways	Free	5.0	Requires iOS 9.3 or later. Compatible with iPhone, iPad, and iPod touch.
Be My Eyes	Free	4.7	Requires iOS 11.0 or later. Compatible with iPhone, iPad, and iPod touch OR Requires Android 4.4 and up
Phone and tablet applications for Visually Impaired People: Scan and Read Apps (Use: IADL)			

Natural Reader	Free	3.0	Requires iOS 9.0 or later. Compatible with iPhone, iPad, and iPod touch.
The MD_evReader App	Free	Unavailable	Requires iOS 7.0 or later. Compatible with iPad.
KNFB reader	GBP 99.99		
Phone and tablet applications for Visually Impaired People: Screen Reading Apps (Use: IADL)			
NonVisual Desktop Access	Free	Unavailable	Computer screen reader https://www.nvaccess.org/
ZoomText **https://www.zoomtext.com/**	UD 400-USD 1,200	Unavailable	Computer screen reader
Job Access with Speech **https://www.freedomscientific.com/products/software/jaws/**	USD 900-USD 1,100	Unavailable	Computer screen reader

COBRA **http://www.bayareadigital.us/products/baum/cobra.html**	USD 649-USD 849	Unavailable	Computer screen reader
Dolphin Screen Reader **https://yourdolphin.com/products/individuals/screen-reader**	USD 955	Unavailable	Computer screen reader
NVDA (Windows)	Free	Unavailable	Computer screen reader
Serotek System Access (Windows)	Free	Unavailable	Computer screen reader
Apple VoiceOver (OS X)	Free	Unavailable	
ORCA (Linux) **https://help.gnome.org/users/orca/stable/introduction.html.en**	Free	Unavailable	Computer screen reader
BRLTTY (Linux) **http://mielke.cc/brltty/**	Free	Unavailable	Computer screen reader
Phone and tablet applications for Visually Impaired People: Voice Recognition Apps (Use: BADL)			
Siri			
Phone and tablet applications for Visually Impaired People: Location and GPS Apps (Use: IADL)			
Microsoft Sounscape	Free	4.2	Requires iOS 12.0 or later.

Ariadne GPS	USD4.99	5.0	Requires iOS 10.0 or later. Compatible with iPhone, iPad, and iPod touch.
BlindSquare	USD39.99	4.2	Requires iOS 9.3 or later. Compatible with iPhone, iPad, and iPod touch.
GetThere	Free	3.8	Requires Android 4.1 and up
Nearby Explorer	USD79.99	4.8	Requires iOS 9.0 or later. Compatible with iPhone, iPad, and iPod touch.
Lazarillo	Unavailable	4.4	Requires Android 4.1 and up

Talking Goggles	IAP		
WalkyTalky	IAP		
Phone and tablet applications for Visually Impaired People: Reading Apps (Use: IADL)			
Audiobooks	Free	4.7	Requires iOS 9.0 and watchOS 3.0 or later. Compatible with iPhone, iPad, and iPod touch. Ap-ple TV.
TextHelp E-Book Reader	IAP		
AIRS-LA	Free	1.0	Requires iOS 8.0 or later. Compatible with iPhone, iPad, and iPod touch.
BARD Mobile	Free	4.4	Requires Android 6.0 and up
NFB-NEWSLINE	IAP		
Sero (Formerly iBlink Radio)	IAP		

Voice Dream Reader	USD14.99	4.6	Requires iOS 11.3 and watchOS 5.0 or later. Compatible with iPhone, iPad, and iPod touch.
Audible	Free/IAP	4.9	Requires iOS 12.0 and watchOS 5.0 or later. Compatible with iPhone, iPad, and iPod touch.

3. HEARING IMPAIRMENTS

3.1 Introduction

The EU report which provides great inputs for this report suggests that AT for deaf and hearing impaired people include three broad classes of devices (Scientific Foresight Unit (STOA), 2018):

i. hearing technology,
ii. alerting devices and
iii. communication technology

i. Hearing Technology

Hearing technology includes devices used to improve the level of sound available to a listener and is, therefore, not made for deaf people with a complete loss of their hearing ability. This technology includes devices for 1) hearing aids, 2) assistive listening devices, 3) personal sound amplification products (PSAPs) and 4) cochlear implants (Hersh and Johnson 2003).

ii. Alerting Devices

Alerting or alarm systems are devices that are suited also for deaf people, because they do not usually require any residual hearing capacity (Lucker and Hersh 2003). They use light or vibrations or a combination of them to alert users that a particular event is occurring. They include 1) clocks and wake-up alarm systems, 2) household device alerts, 3) doorbell and telephone alerts. They may use remote receivers placed around the house or portable pagers. There are also devices designed for baby monitoring, which are able to recognise different types of baby cries and alert the disabled parent accordingly.

iii. Communication Technology

Communication support technology, also known as augmentative and alternative communication (AAC), includes various tools that overall aim at improving communication skills of the disabled person. They are usually classified under two main headings: 1) telecommunication services and 2) person-to-person interactions (NSW Government 2016). Telecommunication services include mainly standard technologies, such as physical and virtual keyboards, touch screens, video calling, captioning for phone calls, text messaging and other social media and text-based technology (e.g. WhatsApp, FB Messenger, Snapchat etc.). There are also systems that use voice recognition software and are able to translate spoken words into sign language or text. AAC for person-to-person interactions includes picture boards, keyboards, touch screens, display panels, speech-generating devices and software. Some of these technologies address also born-deaf people and deaf people who run the risk of losing their speaking ability as well as deaf-blind people. Overall, these devices use technologies that are described in the present report and do not present any additional points of interest.

Table 4: Summary of Types of Aids for Hearing Impairments and corresponding Types of Activities

Type of Aid	Sub-Categories	Type of Activity Ascribed to in this Report	Examples
Hearing Technology	Hearing Aids	BADL	BTE Hearing Aids
	Assistive Listening Devices (ALD)	IADL	T-Coils, FM Systems
	Personal Sound Amplification Products (PSAPs)	BADL	Cochlear Implants
Alarm and Alerting Systems	Clocks and Wake-up Alarm Systems	BADL	
	Household Device Alerts	BADL	
	Doorbell and Telephone Alerts	BADL	
Communication Support Technology or Augmentative and Alternative Communication (AAC)	Telecommunication Services	IADL	Teletypewriter
	AAC for Person-to-Person Interaction	IADL	

3.2 Basic Activities of Daily Life

i. Hearing Aids

Hearing aids are sound-amplifying devices intended to compensate for impaired hearing (Scientific Foresight Unit (STOA), 2018). Most cases of hearing loss are mixed, meaning there is also a damage of the neurosensory tissue, preventing – at least in part – the generation of nervous outputs. Hearing technology can amplify, filter and variously adjust sounds but it cannot generate nervous signals and cannot overcome a deficit of the brain auditory cortex itself. Current hearing aids use digital signals which allow them to be programmed at different frequencies. Digitalization also provides special processing capabilities that help improve speech recognition, noise reduction and overall performance. They may vary in size and features, including *behind-the-ear (BTE)*, *in-the-ear (ITE)* and *in-the-canal (ITC)* devices. A peculiar type of hearing aid, which is considered almost a prosthesis, is the "bone-anchored hearing aid (BAHA)", which is a surgically-implanted device, suited for conductive hearing loss because it allows bypassing external and middle ear anatomical malformations.

Digital vs analog hearing aids:

Before digital hearing aids came on the scene, hearing aids were based on analog technology alone. Analog hearing aids' sound signals are continuous and uniform in flow, so the sophisticated nuances or layers of sound that digital hearing aids have are missing (Cowan & Najafi, 2019). Cowan et al. further note that adapting to different sound environments with analog hearing aids means simply turning up the volume, which is very uncomfortable. Also, with analog hearing aids, one doesn't have the option to reduce background noises – they would also be amplified. According to Cowan et al. digital hearing aids have sound signals that vary and are individual, bringing natural-sounding speech and audio enriched with depth and variation. Therefore, one can really manipulate the sound and volume of digital hearing aids, adjusting the experience to one's personalized specifications.

ii. Personal Sound Amplification Products

Personal sound amplification products (PSAPs) are devices that increase sound levels and reduce background noise. They include a vast array of items, such as amplification systems, stethoscopes, TV/telephone amplification etc. Usually, they use earphones or headphones or have a neck loop for hearing aid users to listen through their hearing aids. They can also have directional microphones that can be angled towards sound sources (NAD 2016). The cochlear implant (CI) is a surgically-implanted sensor that converts sound inputs into electrical outputs that can be transmitted through the auditory nerve. It could be considered as an artificial cochlea, "the cochlear implant does not result in "restored" or "cured" hearing. It does, however, allow for the perception of the sensation of sound" (Scientific Foresight Unit (STOA), 2018). The cochlear implant, which remains controversial, is suggested for adults who have recently lost their hearing (in any case, after having learned speech and language) and for children older than 1 year and younger than 5 years who have profound hearing loss in both ears (Scientific Foresight Unit (STOA), 2018). All current cochlear implants have external and internal components. The external component usually includes a miniaturised microphone, a speech processor, a battery and a transmitter. Sounds are captured by the microphone and send to the speech processor, which is a tiny computer that digitises sounds and sends them to a transmitter, which transmits signals to a receiver implanted under the skin. The receiver captures the signals and sends them to electrodes surgically inserted in the cochlea. The electrodes stimulate the auditory nerve. Researchers are now in progress to develop new low-power signal-processing chips connected to a wirelessly rechargeable cochlear implant with no external hardware (Robitaille, 2010). Research on next generation sound processors – which can filter out noise and help people to focus on specific sounds – also seems promising (Cercone & Naruedomkul, 2013).

3.3 Instrumental Activities of Daily Life

i. Assistive Listening Devices

Assistive listening devices (ALD) can be used by individuals or large groups of people. They amplify the sounds and are particularly helpful when there is a significant background noise. According to the EU report (Scientific Foresight Unit (STOA), 2018), by using different types of energy, ALDs transmit signals to a miniature wireless receiver (tele-coil, also known as t-coil), which turns back signals into sounds. Originally, ALD receivers were headsets; today, t-coils are often installed inside hearing aids or a cochlear implant. There are several types of ALDs: some are designed for large environments, such as conference halls, airports, theatres etc., others are to be used in small settings and for one-on-one conversations. They could use different technologies, including hearing loop systems (which create electromagnetic fields to amplify sounds), frequency-modulated (FM) systems (which use radio signals) and infrared systems (which use infrared light).

Some of the many reasons hearing loops are the preferred assistive listening system by the majority of people with telecoil-enabled hearing aids and cochlear implants, and streamers (Cercone & Naruedomkul, 2013):

a. Easy to Use: To hear clearly, individuals simply switch their devices to the telecoil program and automatically receive clear customized sound. There is no need to arrive early, stand in line, or wait to return equipment after an event or meeting.
b. Quality Sound: A hearing loop sends sound directly to the telecoil receiver in a user's hearing device. The system eliminates most background noise and greatly improves understanding of speech and music. Additionally, the sound received is customized by each user's unique hearing instrument.
c. Discreet: Being able to hear well with a loop is inconspicuous; users do not stand out as being hard of hearing which encourages participation and inclusion.
d. Better Hygiene: For people with hearing aids and cochlear devices, there is also no concern over the sanitation issues associated with wearing headsets or ear buds provided by venues and worn by other users.
e. Versatile: Hearing loops provide effective, seamless communication across the broadest spectrum of environments—from auditoriums, theaters and places of worship, to meeting and class rooms, pharmacies, ticket counters and even in users' homes.
f. Transient Solution: A hearing loop enables clear sound for a person with hearing loss at pharmacies, information desks, subway ticket counters, and taxis, or when passing through airports and train stations.

ii. Alerting or Alarm Systems

Alerting or alarm systems are devices that are suited also for deaf people, because they do not usually require any residual hearing capacity (Scientific Foresight Unit (STOA), 2018). They use light or vibrations or a combination of them to alert users that a particular event is occurring. They include 1) clocks and wake-up alarm systems, 2) household device alerts, 3) doorbell and telephone alerts.

iii. Telecommunication Services

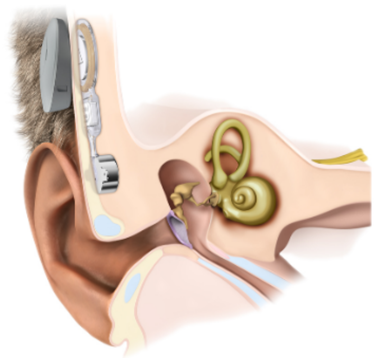
Communication support technology, also known as augmentative and alternative communication (AAC), includes various tools that overall aim at improving communication skills of the disabled person. According to the EU report, they are usually classified under two main headings: 1) telecommunication services and 2) person-to-person interactions. Telecommunication services include mainly standard technologies, such as physical and virtual keyboards, touch screens, video calling, captioning for phone calls, text messaging and other social media and text-based technology (e.g. WhatsApp, FB Messenger, Snapchat etc.). There are also systems that use voice recognition software and are able to translate spoken words into sign language or text.

iv. AAC for Person-to-Person Interactions

AAC for person-to-person interactions includes picture boards, keyboards, touch screens, display panels, speech-generating devices and software (Scientific Foresight Unit (STOA), 2018). Some of these technologies address also born-deaf people and deaf people who run the risk of losing their speaking ability as well as deaf-blind people. Overall, these devices use technologies that are described in the present report and do not present any additional points of interest.

3.4 List of ICT based ATs for Hearing Impairments

Product	Origin	Price	Availability		Description of AT
			Amazon.com	Amazon.in	
Hearing Technology: Hearing Aids (Use: BADL)					
Behind-the-ear (BTE) Digital Hearing Aid 	India	INR 8,500	Yes	Yes	Hearing aids
In-the-ear (ITE) Digital Hearing Aid 	India	INR 12,000-55,000	Yes	Yes	Hearing aids
In-the-canal Digital Hearing Aid 	India	INR 15,000-75,000	Yes	Yes	Hearing aids

Bone-anchored Hearing Aid (BAHA) (without surgery device) https://www.medel.com/hearing-solutions/bone-conduction-system 	Austria	Unavailable	No	No	Hearing aids
Hearing Technology: Assistive Listening Devices (ALD) (Use: IADL)					
Hearing Loop Systems	USA	USD 500 (for smaller venues) – USD 150,000 (for larger venues)	No	No	create electromagnetic fields to amplify sounds
Frequency-modulated (FM) Systems https://www.oticon.com/-/media/oticon-us/main/download-center/amigo/brochure/906-53-011-00-amigo-parent-teacher-guide.pdf	USA	Customized	No	No	which use radio signals

 					
Infrared Systems **Unisar DH900 TV Listener | Wireless Digital TV Audio Assisted Listening Device System**  	USA	USD 80	Yes	No	Which use Infrared light
Hearing Technology: Personal Sound Amplification Products (Use: BADL)					
Digitalized Cochlear Implant	India	Unavailable	No	No	
Alarm and Alerting Systems: Clocks and Wake up Alarm Systems (Use: BADL)					

Clarity AlertMaster Door, Phone, and Clock Alert Device 	USA	USD 216	Yes	No	
Central Alert System Receiver and Clock 	USA	USD 200	Yes	No	
Alarm and Alerting Systems: Household Device Alerts (Use: BADL)					
Krown KA300 Alert System 	USA	USD 319	Yes	No	
Bellman Visit Alert Systems	Swe-den	USD 306	Yes	No	

					
Alarm and Alerting Systems: Doorbell and Telephone Alerts (Use: BADL)					
Deluxe Sonic Alert DB200 Wireless Doorbell and Telephone Transmitter 	USA	USD 115	Yes	No	
Communication Support Technology: Telecommunication Services (Use: IADL)					
Tele Type Writer (TTY) 	USA	USD 499	Yes	No	
Captioned Telephones (Cap Tel)	USA	USD 75	Yes	No	

					
Web Cap Tel 	USA	Una-vailable	No	No	

Product	**Price**	**Rating (App Store/Google Play)**	**Compatibility**
Phone and Tablet Applications for Deaf and Hearing Impaired People: Telephone			
RogerVoice	Free	4.7	Requires iOS 10.3 or later. Compatible with iPhone, iPad, and iPod touch.
Phone and Tablet Applications for Deaf and Hearing Impaired People: Speech to Text (Use: IADL)			
Live Transcribe	Free	4.2	Requires Android 5.0 and up

TextHear – personal	Free download USD8.99	1.4	Requires iOS 9.2 or later. Compatible with iPhone, iPad, and iPod touch.
Hearing Helper	USD2.99	4.7	Requires iOS 10.0 or later. Compatible with iPhone, iPad, and iPod touch.
Phone and Tablet Applications for Deaf and Hearing Impaired People: Sound Loudness Measurements (Use: IADL)			
Sound Meter	Free	2.5	Requires iOS 7.0 or later. Compatible with iPhone, iPad, and iPod touch.
Decibel X	Free (Upgrades to be purchased)	4.6	Requires iOS 9.0 and watchOS 4.0 or later.
Phone and Tablet Applications for Deaf and Hearing Impaired People: Sound Amplifiers (Use: BADL)			
Ear Booster	Free	3.9	Requires Android 5.0 and up
Bio Aid	Free	2.0	Requires iOS 7.0 or later. Compatible with iPhone, iPad, and iPod touch.

Hearing Aid 	Free (Subscriptions to be purchased)	4.1	Requires iOS 9.3 and watchOS 5.0 or later. Compatible with iPhone, iPad, and iPod touch.

4. PHYSICAL IMPAIRMENTS

4.1 Introduction

The idea of "physical impairment" itself is reasonably contestable given the number of varied meanings that this term could assume. One could think of locomotor, mobility, movement or many other impairments related to a person's limbs, muscles, nerves or motor skills along with the term physical impairments (Lawrence, 2017). Although, generally used as an umbrella term to define a variety of disabilities that are not caused by visual and hearing impairments but also are not due to intellectual or learning causations, the term physical impairments generate further ambiguities when trying understand the relevant ATs for them. In qualitative research, as useful a concept as it may be, physical impairments as such was not found to be a formidable concept that should be used in the context of AT. The primary reason for the castigation is the relative lack of definitive focus in determining the daily tasks which are actually hindered by this type of disability. Adhering to HAAT model of disability, not understanding the activity categorization relating to the type of disability constraints largely the efforts of finding the most appropriate technologies.

However, this chapter does not refrain to recognize and list the types of ICT based ATs available for physical impairments amidst of its loose definition. For the purpose of this report such impairments are mostly concerned with physical limitations pertaining to limbs, muscles, nerves or motor skills (Robitaille, 2010; Lawrence, 2017). Following Robitaille's (2010) classification of ATs concerning physical impairments, and also noting the relative lack of robust and cogent studies on the ATs available to physical impairments in comparison to the studies available to the previously discussed visual and hearing impairments, this report also classifies such ATs as;

i. Technologies for daily living, and
ii. Alternative input devices.

i. Technologies for Daily Living

Quite seemingly, ATs concerning this category are aimed at assisting the BADL. Comprised of both low and high tech tools, the most common type of such ATs are the various types of wheelchairs available in the market. Just like the types of canes for the visually impaired and hearing aids for the hearing impaired, wheelchairs continue to the most trusted and commonly used AT overall. There are atleast five types of ATs aiding daily life of physically impaired people:

a. Wheelchairs
b. Prosthetics
c. Environmental Controls
d. Exercise
e. Home and Daily Living

Except for the emerging technologies such as I-limb hands and smart wheelchairs, almost all of the other ATs in this category are non-ICT based tools. Therefore, they will not be listed in this report.

ii. Alternative Input Devices

Alternative input devices replace the standard keyboard and mouse on a computer or laptop. They can also replace finger pointing or a stylus on a PDA. Such devices let users with severe hand and finger- motor impairments activate computers and PDAs in the method that's easiest for them. An alternative input device might be as simple as an ergonomic keyboard for people with arthritis. It can also be a mouse that you control with your head or foot. However, given their assistance at the level of complex instrumental activities of daily work, these will be listed under IADL.

Table 5: Summary of Types of Aids for Physical Impairments and corresponding Types of Activities

Type of Aid	Sub-Categories	Type of Activity Ascribed to in this Report	Examples
Technologies for Daily Living	Wheelchairs	BADL	BTE Hearing Aids
	Prosthetics	IADL	T-Coils, FM Systems
	Environmental Controls		Cochlear Implants
	Exercise	Mostly non-ICT based solutions and are not considered in this report	

	Home and Daily Living	Mostly non-ICT based solutions and are not considered in this report	
Alternative Input Devices	Trackballs	IADL	
	Joysticks	IADL	
	Mounting Arms	IADL	
	Switches	IADL	Access Switched
	Eye Gaze Systems	IADL	
	Foot Control Systems	IADL	
	Mouth Control Systems	IADL	
	Pen Tables	IADL	
	Keyboards	IADL	Expanded Keyboards, One-handed Keyboards
	Sticky Keys	IADL	
	Word Prediction Software	IADL	
	Speech Recognition Software	IADL	
	Headsets	IADL	
	Telephones	IADL	
	Mobile Phones	IADL	

4.2 Basic Activities of Daily Life

i. Smart Wheelchairs

People with cognitive/motor/sensory impairment, whether it is due to disability or disease, rely on power wheelchairs (PW) for their mobility needs. Since some people with disabilities cannot use a traditional joystick to navigate their PW they use alternative control systems like head joysticks, chin joysticks, sip-n-puff, and thought control (Leaman & Hung , 2017). According to Leaman et al. in many cases PW users have difficulties with daily maneuvering tasks and would benefit from an automated navigation system. To accommodate the population of individuals who find it difficult or impossible to operate a PW, several researchers have used technologies originally developed for mobile robots to create smart wheelchairs. In this sense, PW are not treated as ICT based ATs for the purpose of this report.

A smart wheelchair (SW) is a PW to which computers, sensors, and assistive technology are attached. A smart wheelchair typically consists of either a standard PW base to which a computer and a collection of sensors have been added, or a mobile robot base to which a seat has been attached (Leaman & Hung , 2017). Therefore, SW will be treated as an ICT based AT aiding the physically impaired people. However, as a major setback concerning this promising technology, the still "under-experiment" status of these make them still not available in the market for consumer use. Even for the purpose of this report, they are treated as emerging technologies rather than readily available ATs.

(a) (b) (c) (d) €

Figure 14: Examples of modern PW form factors: (a) stair climbing iBot [discontinued 2008], (b) Australia's Ability in Motion, standing wheelchair, (c) the Tank Chair, (d) Chinese Observer remains level on all-terrain, and (e) Patrafour by Toyota Motor East Japan.
Source: (Leaman & Hung , 2017, p.2)

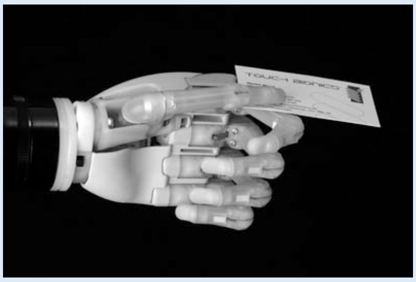
ii. iLIMB Hands

This is a specially manufactured smart limb in the prosthetics category. The iLIMB Hand by Touch Bionics is an electric limb for people who have lost one or two hands or arms. The iLIMB Hand permits six separate movements, one for each digit and another for the wrist (Robitaille, 2010). Again, this too is still in experimental status and not at a marketed level.

4.3 Instrumental Activities of Daily Life

All of the alternative input devices that was mentioned previously will be listed under IADL given that almost all of such devices include instrumentality with a computer or a mobile phone. Wheelchairs and smart limbs were the only ATs that could be categorized under BADL concerning physical disabilities.

4.3 List of ICT based ATs for Physical Impairments

Product	Origin	Price	Availability		Description of AT
			Amazon.com	Amazon.in	
Technologies for Daily Living (Use: BADL)					
iLIMB Hand 	USA	USD 60,000-USD 120,000	No	No	Prosthetics
Alternative Input Devices (Use: IADL)					
Trackballs 		USD 30-USD 100	Yes	Yes	Trackballs
The Tash Joystick 		USD 20-USD 40	Yes	Yes	Joysticks
Mounting Arm		Unavailable	No	No	Mounting Arms

					
Pneumatic Switch 		Unavail-able	No	No	Switches
Access Switch 		USD 60-USD 100	Yes	No	Switches
Wobble Switch	New Zea-land	Unavail-able	No	No	Switches

					
BIGmack Communicator 	USA	USD 135	No	No	Switches
EyeGaze 		Unavail-able	No	Np	Eye Gaze Systems
HeadMouse Extreme		Unavail-able	No	No	Eye Gaze Systems

					
NoHands Mouse 					Foot Control Systems
Integra Mouse 					Mouth Control Systems
Jouse 3 Mouth Control System 	USA	Unavailable	No	No	Mouth Control Systems
Bamboo Tablet /Wacom Tablet 		Unavailable	No	No	Pen Tables

Intellikeys 		Unavail-able	No	No	Expanded Keyboards
QWERTY keyboards 		Unavail-able	No	No	Miniature Keyboards
One-handed Keyboard 		USD 25-USD 80	Yes	Yes	One-handed Keyboards
N-Type **https://patient-innovation.com/post/538**					Onscreen Keyboards
Windows onscreen keyboard					Onscreen Keyboards

Windows Sticky Keys					Sticky Keys
Gus!		Unavailable			Word Prediction Software
EZ Keys from Words+	USA	USD 298	No	No	Word Prediction Software
Windows Speech Recognition		Free	N/A	N/A	Speech Recognition Software
Apple's built- in Speakable Items		Free	N/A	N/A	Speech Recognition Software
MacSpeech Dictate		Free	N/A	N/A	Speech Recognition Software
Voice Tracker™ Array Microphones (Tracker I, II and III) 	USA	USD 340	Yes	No	Headsets
Talkfar Wireless Voice Recognition USB Microphone	USA	USD 199	Yes	No	Telephones

					
Vocalize Bluetooth Cell Phone Voice Control System for Power Wheel-chair 	USA	USD 1,111	Yes	No	Mobile Phones

5. MAJOR ACTIVITIES OF LIFE

5.1 Introduction

As pointed out in the introduction chapter before, this report listed the relevant ICT-based ATs not according to the utility of them, but according to the type of technology and the daily activity concerned. Therefore, as a result, there aren't any new ATs that can solely be classified as those that assist in major activities in life such as education, finance and health. However, given the fact that many education inclusion, financial inclusion and health inclusion issues and barriers have been continuously flagged in both LIRNEasia's research and in other literature, this chapter will organize some of the essential ATs that assist in those domains in a single place. To avoid any misunderstanding, this chapter does not introduce new ATs, but attempts to organize what is already listed under the three inclusion domains for the reader's convenience.

5.2 Education Inclusion

AT products for inclusive education also involves variations of the products that have already been discussed and listed in the previous chapters. However, for ease of navigation those ATs that assist in educational purposes can be categorized as;

i. AT tools for reading
ii. AT tools for writing
iii. AT tools for Math
iv. AT tools for Auditory Processing Disorder

Table 6 lists some of the fundamental ATs recommended to be used in a classroom context. Table 7 presents a flowchart of both ICT based and non-ICT based ATs for visually impaired students that the Wisconsin Assistive Technology Initiative (WATI) – an AT program based in USA that has published a number of reports and policy briefs on school related ATs for disabled children – recommends.

Table 6: ATs for Education Inclusion

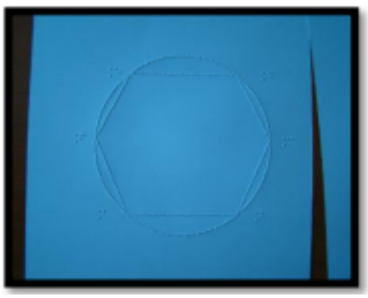
Type of Product	Products	Remarks
Assistive Technology Tools for Reading (Use: Visually Impaired)		
Text-to-speech **(TTS)**	Portable Reading Solution 	Listed in section 2.4
Audiobooks and digital TTS books	Audio book apps	See list in section 2.4
Optical character recognition **(OCR)**		(OCR) reads aloud text from images and pictures. You can use OCR by taking photos of worksheets and paper documents, and even objects like street signs. They can also scan documents in. OCR can read words from pictures on web pages (such as image files, like JPG). Like TTS, OCR uses computer-generated voices.

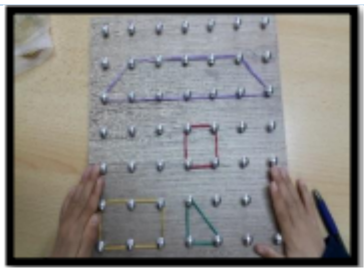
Graphic organizers	 	Graphic organizers are visual representations, like diagrams and mind maps, of ideas and concepts. Students can use graphic organizers to take notes while reading, which can help with comprehension. Graphic organizers can be digital or pen and paper.
Annotation tools		Annotation tools let you take notes and write comments while reading. This can make it easier to retain information. Annotation tools can be part of software or apps, or they can be traditional pens, markers, and sticky notes.
Display control		Display control allows you to control how text is displayed. When reading on a screen, they can change the font, font size, color, and spacing of text. You can also cover (or mask) parts of the screen to lessen distractions while reading.
Dictionaries and thesauri	Talking Dictionaries: https://talkingdictionaries.app/	Dictionaries and thesauri let you look up words you

		don't understand when reading. A picture dictionary is a popular tool that uses images to define words. And a talking dictionary reads definitions aloud.
Assistive Technology Tools for Writing		
Handwriting tools		Handwriting tools can help people who have trouble with motor skills. For example, a pencil grip makes it easier to hold a pencil properly. These are mostly non-ICT based tools.
Keyboards and touchscreens	Braille key boards Braille screens  	See list in section 2.4
Dictation (speech-to-text)	Online sources: https://speechnotes.co/ https://dictation.io/speech	Dictation (speech-to-text) allows you to write by using your voice. As you

		speak, the words appear on the screen. Keep in mind that to use dictation, you have to be able to speak clearly. You also need to learn verbal commands for things like punctuation. Some dictation software can also be used to convert audio recordings into digital text.
Word prediction	Online sources: https://www.understood.org/en/school-learning/assistive-technology/assistive-technologies-basics/word-prediction-technology-what-it-is-and-how-it-works	Word prediction suggests correct spellings of words after only a few letters are typed. Word prediction sometimes uses "word banks" (commonly used words in a topic area) to help writers come up with words and complete their sentences. *Unlike dictation, word prediction requires using a keyboard.*
Assistive Technology Tools for Math		
Calculators	Talking Desk Calculators (USD12.95)	But kids who struggle with math may prefer calculators that have buttons with large numbers and symbols. There are many kinds of calculators, from graphing

	 TI ViewScreen Solutions (Current price: USD300)  VisAble Scientific Calculator (Current price: USD269) Leo Braille Display Calculator (Current price: USD1000) Accessible Graphing Calculator (Current price: USD75)	calculators to computer apps. Some can even solve equations with variables.
Math notation tools	Maxima computer algebra system: http://maxima.sourceforge.net/ Mathml: https://www.w3.org/Math/	Writing out equations by hand can be challenging for people who have trouble writing numbers and symbols. And most traditional word processors aren't great

	Math Player: http://www.dessci.com/en/products/math-player/	at handling math symbols. *Mostly non-ICT based tool.*
Graph paper		Graph paper has a grid that makes it easier to line up numbers and symbols in math problems. That's important when keeping track of things like place value. Students often write on traditional graph paper with a pencil. Some may prefer graph paper that has large squares. There's also digital graph paper. *Mostly non-ICT based tool.*
Graphing tools		Graphing tools help with graphing the path created by an equation.
Drawing tools	Drawings on a Braille paper from a Braille printer  Geoboard	Drawing tools help with drawing lines, shapes, angles, and other geometric features. Traditional classroom tools like rulers, stencils, and protractors can help with drawing. There also are specific computer programs for drawing. Students who study geometry or trigonometry may find

		them helpful. *Mostly non-ICT based tool.*
Equation-solving tools		Equation-solving tools are digital tools that help students work with equations. Unlike calculators, equation-solving tools don't solve a problem. They help students figure out *how* to solve a problem. *Mostly non-ICT based tool.*
Manipulatives		Manipulatives are objects that let you solve math problems in alternative ways. They can also illustrate math concepts. A classic example is the number line. *Mostly non-ICT based tool.*
Assistive Technology Tools for Auditory Processing Disorder		
Personal listening devices (PLD) **Captioning**	FM Systems 	Personal listening devices (PLD) can help kids hear a teacher's voice more clearly. With a PLD, the teacher wears a clip-on wireless microphone. The mic transmits her voice directly to a student's personal speaker or earpiece.

		Some PLDs are called frequency modulation (FM) listening systems because they rely on the same FM frequencies radio stations use. Some newer PLDs use Wi-Fi or Bluetooth to transmit a voice. *Referred to in section 3.4.*
Sound field systems		Sound field systems are specialized speaker systems for classrooms, which often have sound issues. There may be areas where sound echoes or is muffled. A sound field system broadcasts the teacher's voice to speakers placed in certain locations in the room. This helps to distribute the teacher's voice evenly throughout the classroom, so all students can hear it well. Some systems include a pass-around microphone for kids to use during class discussions. *Referred to in section 3.4.*
Noise-canceling headphones	Headphones	Noise-canceling headphones can help block out background noise for kids

		who are sensitive to sound. Kids may find it helpful to connect their headphones to a white noise app that plays sounds like rain or static. If kids need to listen to audio, they can listen *through* the headphones to help filter out distracting background noises. *Mostly non-ICT based tools.*
Audio recorders	Digital Voice Recorders (Current price range: USD50 - USD300) 	Audio recorders allow kids to record classroom lectures or discussions. This way they can listen to a lecture several times if they didn't comprehend it well enough the first time. It also may help to be able to pause the recording or play it at a slower speed to improve understanding. Some note-taking apps or devices allow kids to synchronize their handwritten or typed notes to an audio recording. This can make it easier to navigate an audio recording.
Text-to-speech (TTS) software		Referred to above.

Table 7: Wisconsin Assistive Technology Initiative's Recommended ATs for Schools

Computer Access	Technology for Academic Areas			Expanded Core Curriculum		
Computer access	**Reading**	**Writing**	**Math**	**Pictorial Information**	**Note-Taking**	**Mobility**
Color scheme	Glasses	High contrast pen	Large print measuring tools (rulers, protractors)	Enlarged format	Slate and stylus	Cane
Large operating system features	Color filter	Portable word processing device	Large key calculator	CCTV	Tape or digital recording device	Monocular
Built-in Magnification	Slantboard	Typing with audio support	Tactile measuring devices	Models or objects	Computer-based recording software	Braille/talking compass
Fully featured magnification	Large print	Braillewriter	Abacus	Tactile graphics	Electronic Braille notetaker	Electronic Travel Device
Magnification with screen reader	Optical magnifier	Typing with Braille support	Talking calculator	Tactile-audio graphics		GPS Device
Screen reader	Electronic magnifier	Electronic Braille notetaker	Models or 2D & 3D geometric shapes			
Screen reader with Braille device	CCTV	Voice Recognition	[illegible]			
	Monocular					
	CCTV with distance camera					
	Audio text					
	Computer based reading software					
	Electronic Braille					

Source: Assessing Students' Need for Assistive Technology (for visually impaired), The Wisconsin Assistive Technology Initiative (2009)

5.3 Financial Inclusion

A report on financial inclusion by the Global Initiative for Inclusive ICTs (Global Initiative for Inclusive Information and Communication Technologies, 2015) stipulate the below listed areas where ATs are expected to assist the users. ATs that are operative in each category are listed in table 8.

i. In-branch banking

ii. Phone banking
iii. Internet banking
iv. Payment terminals and Kiosks
v. Mobile banking

Table 8: ATs for Financial Inclusion

Product	Description
In-branch Banking	
Braille, large print and audio	Non-ICT based solutions
Cheque and credit-slip templates 	Braille cheques, mostly non-ICT based.
Note gauges	Assists in identifying currency notes. A simple mobile app also can perform the function.
Sign Language Interpretation in branch	
Hearing loops in branch	As already discussed in chapter 3, these improve the sound quality if you use hearing aids.
Signature stamp	Signature stamps can be useful if you find signing your name difficult.
Phone Banking	
Sign Language interpretation from home	
Textphone (or 'minicom') 	A textphone has a keyboard and a screen on which messages sent and received are displayed.

Next Generation Text Relay (NGT) **NGT App**	If you can't hear on the phone the Next Generation Text Relay assistant will type what the other person is saying so that you can read their words. If you are unable to speak on the phone, you can type your message / query and the Next Generation Text Relay assistant will speak your words to the other person.
Internet Banking (See web accessibility details below)	
Live Chat	Mostly suitable for hearing and physically impaired people.
Payment Terminals and Kiosks	
Talking ATMs 	Talking ATMs are useful for anyone who wants to use an ATM service and cannot use or struggles with the screen instructions, such as customers who are blind or have dyslexia. Things you can do at an ATM include getting cash, checking your account balance and topping up your pay-as-you-go mobile phone.
Chip and signature	Chip and signature cards can be very useful if a person has difficulty inputting a PIN. It means you can use your signature rather than entering a PIN when using your debit or credit card. When one uses your chip and signature card, the retailer will automatically ask the person to sign instead of keying in a PIN.
Mobile Banking	See web accessibility details below

The accessibility of internet banking and mobile banking depends on the financial institutions following the Web Accessibility Guidelines 2.0, a set of guidelines stipulated by the

World Wide Web Consortium (W3C) used to ensure web sites are designed and written in a way that makes them accessible to everyone. This means that:

a. The financial institutions only use strong colour contrasts
b. Headings are used correctly to make them readable through screen readers
c. Links do what they say. We don't use 'click here'
d. Tables are laid out in tabular form with headings and summaries
e. The financial institutions use style sheets to determine the presentation of their website - this assists those using screen reading devices
f. Where they use images, institutions must use alternative text so that those people who cannot see the image can read the text. These can be read by screen reading devices (already discussed before).

5.4 Health Inclusion

It is observed that except for the talking devices (for visually impaired) and hearing devices (for hearing impaired) that audio-narrate a particular task/function rest of possible health inclusion areas have already been listed in the previous chapters. For example, in-hospital accessibility and mobile health services seem to overlap with what was discussed and listed previously under in-branch banking and mobile banking concerning financial inclusion. Besides, literature is also limited that specify ATs that cater solely to health contexts. As a result, we can state that health inclusion approximately refers to;

i. Talking and Hearing Devices
ii. In-hospital Accessibility
iii. Mobile Health Services

Table 9: AT for Health Inclusion

Product	Description
Talking Devices	
D20 2 in 1 TALKING Blood Glucose and Blood Pressure Monitor (USD 90) 	Assists visually impaired people to test their own blood glucose levels with an audio operating guide and easy instructions.
HealthSmart Talking Upper Arm Blood Pressure Monitor - English+Spanish (USD 80) 	Assists visually impaired people to test their own blood glucose levels with an audio operating guide and easy instructions.
DigiScan Multi-Function Talking Thermometer (USD 50) 	This talking thermometer offers a quick and accurate reading, and reduces the eye strain of having to read the temperature. With this low vision product, people no longer have to squint and strain their eyes.
Hearing Impaired Model E-Scope II w-Extra Large Heaphones (USD 475)	Amplifies up to 120 dB SPL(sound pressure level) for hearing impaired people.

	
In-hospital Accessibility	Corresponds to many embedded technologies discussed before.
Mobile Health Services	Corresponds to web accessibility guidelines presented before.

6. EMERGING TECHNOLOGIES

6.1 Visually Impairments: Bionic Eyes

New technology approaches are under development, but it is not easy to predict which of them will finally emerge. Since the late 1990s, research has been in progress to create devices that can interface with neurons in the retina or in the optic nerve (“bionic eyes”). They are based on micro light sensors, which can be implanted in the eye and send electrical signals to nerve cells. For instance, the ‘artificial silicon retina’ (ASR) is a tiny computer chip to be implanted in a surgically created sub-retinal pocket (Scientific Foresight Unit (STOA), 2018). The ASR is provided with five thousand micro solar cells that turn light into electrical signals. When the device is first switched on, patients see flashes of light, but in the course of a few weeks, the brain learns to convert these flashes into meaningful shapes. For now, the images are often black and white and very grainy (Scientific Foresight Unit (STOA), 2018). ‘Retinal prostheses’ are very close to bionic eyes. The main difference is that the implanted device, interfaced with the optic nerve, is not able to sense light by itself but receives data signals from a miniature video camera mounted on special glasses.

6.2 Hearing Impairments: Smart Glasses/Google Glasses

Several online reports indicate that there is an accelerated development of smart devices. This technological boom is based on rapidly growing software and hardware requirements not only from the users, but also from producers (Scientific Foresight Unit (STOA), 2018). The aim of ‘Smart Glass’solution is to digitally capture the ambient sound and based on its evaluation using neural networks, to present users needed information in a text form. To accomplish this smart solution, modern cloud services and a special smart device are used – Google Glass (abbreviated GG). These smart goggles offer sensors with the ability to compensate user’s disadvantages (Scientific Foresight Unit (STOA), 2018). In the direction of facilitating the work for hearing impaired people, authors intend to further develop this technology and offer solutions in the following research to make daily life easier for people with hearing impairment.

Figure 15: Smart Glass

New and advanced cochlear implants are in progress (Scientific Foresight Unit (STOA), 2018). According to the EU report, other emerging technologies for deaf and hearing impaired people are essentially applications of existing technologies, such as

a. 'Google glasses' equipped with sign language interpreters (Figure 15); they exploit a number of apps (e.g., Hand Talk, Mimix3D, ASL Translator, ProDeaf Translator, etc.) already available on the market, which display an on-screen avatar who translates the words heard into sign language; the system projects the interpreter on the screen of the glasses;
b. various systems to provide 'real-time captioning', for instance, an app developed at Georgia Tech, working with a smartphone. The person with whom the glass wearer is speaking simply talks into the phone and the transcribed text automatically appears within the glass.
c. purpose-designed software for laptops and tablets;
d. 'several smartphone applications.'

Figure 16: Sign Language Avatar
Source: (Scientific Foresight Unit (STOA), 2018)

6.3 Physical Impairments: Smart Wheelchairs

A study conducted by Worcester Polytechnic Institute (WPI) showed that users who are accustomed to their wheelchairs have little to no tolerance for the failures of "new features," which means full autonomy plays an important role in users' acceptability. Overall, people are open to using a robot that assists them in performing a task in an environment with other humans. These" Co-robots" provide their user with independent mobility. Smart Wheelchairs (SWs) have to be safe and their operations must be reliable under any conceivable circumstance (Leaman & Hung , 2017). This is especially true for SWs, where the user has a disability and may be quite frail.

According to Leaman and Hung, current Powered Wheelchair (PW) users still have many difficulties with daily maneuvering tasks, and would benefit from an automated navigation system. Future SW users will be able to select from several autonomous or semi-autonomous operating modes, using the input methods they are most comfortable with. They will direct their SW to navigate along preprogrammed routes with little physical or cognitive effort indoors and out, passing through doors and up-and-down elevators. The SW in the future is supposed tp communicate with the user when it is appropriate in order to reduce anxiety, and build an individualized profile. These profiles will track such variables as preferred input method, wheeling speed, turning speed, and amount of verbal feedback, just to name a few. Leaman and Hung further note that future research plans should focus on developing novel navigation algorithms to allow SWs to autonomously and safely navigate in complex environments. These are not trivial tasks since they require online calibration and sensor fusion of multiple sensor sources including laser scanners, camera, IMU, encoder and GPS, etc.

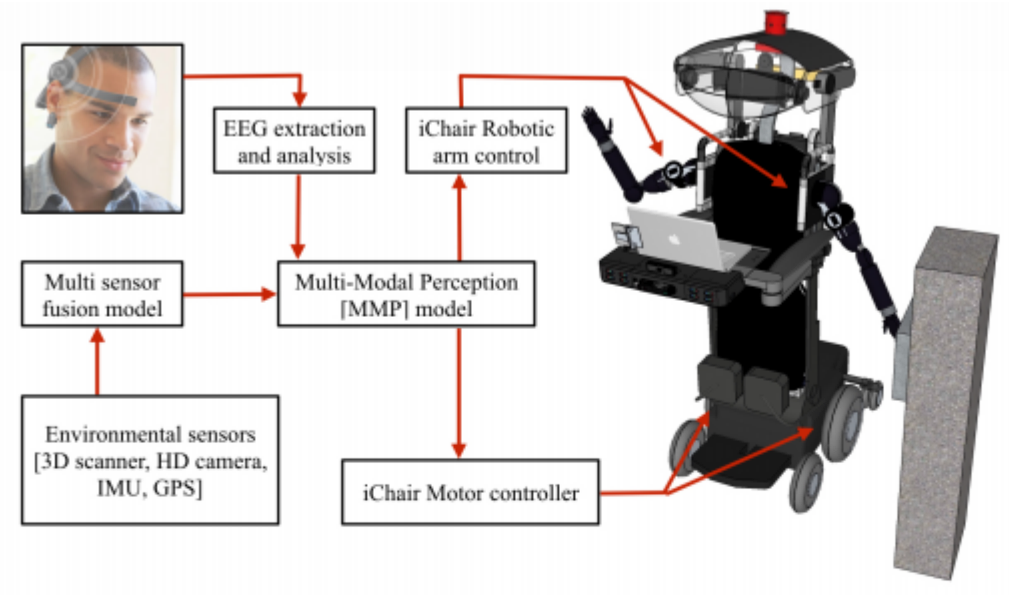


Figure 17: Example diagram of the human-iChair interaction model

Human-Smart Wheelchair Interaction Model plays a vital role in the formation of a SW (Leaman & Hung , 2017). The reinforcement learning technique could be utilized to build an efficient interaction model between user and SW. The developed model may take into account sensor feedbacks, such as from Emotive sensors and various environment sensing sensors including Oculus virtual reality sensors, laser scanners, cameras and global positioning system (GPS). The SW uses these control signals to navigate and operate its robotic arms (see Figure. 17). Human user thinking will be captured and analyzed through an advanced signal processing model. The output signals will control the operations of the SW including wheel motors as well as robotic arms. A shared control scheme could be developed to allow effective collaboration between user and SW, as well as to adapt SW's assistance to the variations in user performance and environmental changes.

Smart Wheelchair with Smart Home SWs will be integrated into the smart home, providing a seamless user experience and control over all household appliances (Leaman & Hung , 2017). When the users are outdoor a retractable roof will provide shelter from the elements, and additional safety at night while driving in traffic. Further to Leaman's and Hung's predictions, optical stereoscopic and spherical vision imagery will be combined with infrared laser data to produce a virtual point cloud matrix of the user's surroundings. Objects in the matrix are identified using machine vision, visual tracking, and gesture recognition algorithms. Localization information from the IMU and GPS, onboard data collected, and bluetooth beacon data flooding public spaces, will all help guide the SW to a particular destination.

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