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Assistive technologies for people with disabilities

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Assistive technologies for people with disabilities

In-depth analysis

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Abstract

Assistive technologies (ATs) are designed to improve the functional capabilities of people with disabilities. Some are relatively low-tech and very familiar, such as such as reading glasses, crutches and hearing aids. Others are more advanced, using cutting-edge science and technology, with future ATs under development that could have a huge impact on all our lives.

The focus in this study is on ATs for three specific disabilities: blindness and visual impairments, deafness and hearing impairments, and autism spectrum disorders. These three disabilities exhibit both similarities and differences in terms of their implications for ATs. A description of the regulatory environment, including international agreements and EU regulations regarding disabilities and technologies, is followed by four case studies on Germany, Hungary, Portugal and Sweden. The study includes a review of the ATs currently available and future ATs at various stages of development, and also a survey of people from each disability group, focusing upon their perspectives and needs with regard to ATs. This is supplemented by expert interviews and a stakeholder workshop.

Through this combination of primary and secondary research, several social, technical, ethical, demographic, regulatory, economic and environmental trends are identified. These are used to compile four explorative scenarios about the future of ATs, and to develop social, ethical and legal reflections on the role of current and future initiatives of the European Parliament.

The study finds that current and future ATs could have a positive impact, but identifies problems with one-size-fits-all approaches. Alone, ATs are insufficient to foster a more inclusive society. While waiting for future ATs, more can be done to make effective use of current ATs and implement existing regulatory frameworks. Other steps include targeting wide attitudinal and social change, encouraging co-creation of future ATs, and promoting the emergence of AT professionals.

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This document presents the key insights of the STOA project 'Assistive technologies for the inclusion of people with disabilities in society, education and jobs'. The project was requested by the European Parliament's Science and Technology Options Assessment (STOA) panel. It was carried out by the European Technology Assessment Group (ETAG), led by the Institute for Technology Assessment and Systems Analysis at Karlsruhe Institute of Technology (ITAS/KIT) and including Fraunhofer ISI, The Institute of Technology Assessment (ITA) and Responsible Technology (RT), and managed by the Scientific Foresight Unit (STOA) within the Directorate-General for Parliamentary Research Services (DG EPRS) of the European Parliament.

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1. Introduction

Assistive technologies (ATs) are designed to improve the functional capabilities of people with disabilities. Some are relatively low-tech and very familiar, such as such as reading glasses, crutches and hearing aids. Others are more advanced, using cutting-edge science and technology. Future ATs currently under development could meanwhile have a huge impact on all our lives. While some ATs are specialist devices, of interest only to people with specific disabilities, others have several features in common with mainstream technologies. Indeed, some of them are standard mass market products, configured for the individual user just like any other. For example, tablet computers can be used to provide live sign-language interpretation. A number of niche AT applications have also developed into mainstream technologies. These include the text-to-speech and verbal command functions of smartphones, which were originally developed for people with visual impairments. The strong links between assistive and mainstream technologies is not really that surprising since *all* technologies are assistive. They all help people use their varied abilities to do the things that they want or need to do, from commuting to cooking and communicating. However, as highlighted in a previous STOA publication, even if ATs may help to overcome some barriers to inclusion, they can only go so far. While future ATs might do more to help, there is no need to wait for them. Social action and existing technologies can be deployed to start building a more inclusive society today.

In June 2015, STOA held an event to explore the role of ATs in fostering an inclusive environment for people with disabilities. This led to a project on how current and future ATs can foster the inclusion of people with disabilities in society, education and jobs. The project was launched in February 2016, and ended in September 2017. It followed STOA's fledgling foresight methodology, which starts with the identification of broad trends and their potential impacts, before moving on to the development of scenarios to support the exploration of possible futures and, finally, back to the present day and reflections on how it might be possible to prepare for and shape the future through European regulatory instruments as well as other forms of action. The project was carried out by the European Technology Assessment Group (ETAG), led by the Institute for Technology Assessment and Systems Analysis at Karlsruhe Institute of Technology (ITAS/KIT) and including Fraunhofer ISI, The Institute of Technology Assessment (ITA) and Responsible Technology (RT). The project findings are published in three parts, Part I: Regulatory, health and demographic aspects, Part II: Current and emerging technologies, Part III: Perceptions, needs and opportunities and Part IV: Legal and socio-ethical perspectives. An accessible video that communicates the key findings is also available.

This briefing presents a summary of some of the study's key findings. It draws upon its three outputs, which were written by the project team mentioned on page 2. First, it introduces the three disabilities

that are considered in the project, and presents an outline of the regulatory context at national, European and international levels. The subsequent section describes current and emerging ATs for each of the three disabilities, as well as some overall trends in the development of ATs. This is then followed by the results of a survey of a wide range of current and potential users of ATs as well as experts' insights gained through interviews and a workshop. The penultimate section describes some key future trends for ATs, culminating in a set of scenarios and a legal analysis before the report concludes with reference to the action that could be taken today to prepare for the ATs of tomorrow.

2. Understanding blindness, deafness, and autism spectrum disorders

The focus for the study was ATs for three specific disabilities. The first, blindness and visual impairments, ranges from mild disorders to severely limited visual perception and blindness. The second, deafness and hearing impairments, also follows a scale from minor disorders and range limitations to more severe impairment and deafness. Autism spectrum disorders (ASD), the third, are lifelong developmental disabilities that vary from Asperger syndrome, where intelligence and verbal communication may be preserved while non-verbal communications skills such as eye contact and facial expression are affected, to more severe disorders combining difficulties in communication and learning with hypersensitivity.

Read more about the causes and effects of these three disabilities in Part I: Regulatory, health, and demographic aspects.

Deafness and hearing impairment can be caused by a range of disorders of the outer, middle and inner ear, the cochlea, cranial nerve or central auditory system. The occurrence of hearing impairments increased substantially between 1990 and 2010. This may be correlated to the ageing population, since a clear link has been identified between hearing loss and age with around 10 % of all adults suffering some form of hearing impairment, a figure that rises to 50 % for people in their 80s. However, it should be recognised that gradual age-related hearing impairments present very different challenges to other forms of deafness. Blindness and visual impairments can be caused by disorders of the external layer (the cornea and sclera), the chamber surrounding the eye, or the inner layer (the retina). European prevalence of vision loss and blindness is estimated at 2.9 % and 0.3 % respectively. However, loss of vision, like hearing impairment, correlates with ageing, and around 81 % of those with severe impairments or blindness are over 50 years old. As such, the number of people with visual and auditory impairments is expected to rise as the population ages. Severe and lifelong loss of vision needs to be considered alongside more common visual impairments that can be easily corrected or treated. The causes and prevalence of ASD, meanwhile, are not well known, although genetics are thought to play an important role. Usually, ASDs manifest themselves early in life and, unlike blindness and deafness, their prevalence is not linked with ageing.

Clearly, the three disabilities differ in their causes and effects, yet they share some common ground. While some individuals may show outward signs of their disability, e.g. in the use of guide dogs, all three disabilities can be invisible to others. Most notably, each of the three disabilities can present barriers to the individual's participation in society, education and employment. For example, they can hamper those tasks that rely upon reading texts, participating in verbal conversation and engaging in complex social interactions. Another common theme that is particularly important for this study is identified in the increasing use of assistive technologies to help overcome some of these barriers to participation. It will also be seen that mainstream technologies, such as the smartphones that many people use on a daily basis, are increasingly difficult to distinguish from technologies that are specifically designed to assist people with disabilities.

There are also crucial differences between these disabilities however. For example, people with hearing impairments often have a better position in the labour market than those with visual impairments or ASDs because their disability may appear later in life, once they have already established their careers. While visual impairments also correlate strongly with ageing, the hearing impaired can also benefit from

both assistive and mainstream technologies that enable their inclusion in the workplace to a greater extent than many other people with disabilities. For example, in many workplaces, emails are now much more common than phone calls. In general, people with congenital disabilities can find it harder to enter the labour market in the first place, this includes autistic people who can face prejudice from the earliest stages of their working lives.

It should be noted here that there are communities that reject the definition of disability and call for acceptance of their individual differences. For example, some members of the deaf community represent themselves as a minority group with their own language, cultural traditions and heritage. Likewise, the autism rights movement has rejected the association of autism with disease and disability, describing ASDs as an expression of neurodiversity.

3. The regulatory environment

It is important to consider the regulatory environment in terms of both assistive technologies and the inclusion of people with disabilities in society, education and jobs. Relevant regulations are present at international, EU and Member State levels. Higher level regulations are subject to differences in interpretation and implementation across Member States, leading to different regulatory environments across Europe. The present study includes case studies for four countries – Germany, Hungary, Portugal and Sweden – to capture some of these differences. Each case study included reviews of academic and policy literature as well as interviews with experts.

Read more about international, European and national regulatory context for people with disabilities in Part I: Regulatory, health, and demographic aspects

The United Nations Convention on the Rights of People with Disabilities (CRPD) came into force in May 2008 and was the first legally-binding international instrument to which the EU and its Member States became party. Its 50 articles and principles build a comprehensive framework for the empowerment of people with disabilities. The measures target non-discrimination as well as shifting the way that disabilities are considered in society, moving from a medical model, whereby people with disabilities receive treatment and welfare towards a more social model, whereby provisions are made to ensure that the environment is made accessible to people with disabilities as active and equal members of society. This change of perspective effectively repositions the problem away from people's impairment to the barriers to their inclusion presented by their social and physical context. Following an EPRS analysis, the CRPD does not establish new rights for people with disabilities, but reaffirms and codifies existing rights while providing guidance on how to achieve them, e.g. through the concept of reasonable accommodation. Reasonable accommodation refers to the provision of different treatment for people with different (relevant) circumstances and characteristics. It is complementary to anti-discrimination measures, which demand similar treatment for people who have similar (relevant) circumstances and characteristics. In the CRPD, reasonable accommodation means making modifications and adjustments to ensure that people with disabilities can be treated on an equal basis without imposing a disproportionate or undue burden upon the employer, the denial of which is considered to be a form of discrimination.

At EU level, the CRPD is implemented via the European Disability Strategy (EDS), which builds upon the experience of the earlier disability action plan to empower people with disabilities to enjoy their full rights as EU citizens, and to remove the barriers presented by their everyday social and physical context. The focus on autonomy and rights to full inclusion did not entail a radical, paradigm shift since previous EU disability frameworks also took a rights-based approach. A report on the implementation of the EDS, adopted by the EMPL committee in October 2017, called for comprehensive implementation of the CRPD while highlighting the role of ATs in education and employment, and encouraging the EU institutions to improve the accessibility of its meetings through current ATs while monitoring AT development with a view towards improving accessibility in future.

Non-discrimination towards people with disabilities is part of the European Pillar of Social Rights, and the EU is obliged to respect the Charter of Fundamental Rights of the EU including its Articles 21 and 26, on non-discrimination and the integration of persons with disabilities respectively. The Treaty on the Functioning of the European Union includes Articles 10 and 19 on combating discrimination on the basis of disability. There are also references to disability in European laws pertaining to more specific areas of our lives that fall within EU competence, including transport networks, telecommunications and the labour market. However, several sectors that are of great importance for the inclusion of people with disabilities – such as social security and education – fall outside the jurisdiction of the EU, and are managed exclusively by the individual Member States.

In 2011, the EC announced the European Accessibility Act (EAA) which aims to harmonise accessibility requirements for several products and services by establishing accessibility principles, rather than imposing specific technical specifications. While many stakeholders welcome the initiative in the context of meeting the responsibilities set out in the CRPD, there are differing perspectives on how that should be achieved and how implementation should be evaluated. An analysis for the PETI committee set out the views of several key actors and recommended that the act also cover payment terminals and household electronic appliances. While the EAA does not focus on ATs, it is part of a wider trend whereby assistive and mainstream technologies are increasingly assistive.

Some ATs are classified as medical devices and are, therefore, covered by the Medical Devices Directive. This imposes higher criteria on the devices, which may lead to improvements but also makes it more expensive and time consuming to reach the market. Classification as a medical device may also affect the perceived value of a technology.

Rules governing technologies are also an important part of the regulatory context of ATs. It is important to consider the data protection and privacy challenges that face the many producers and users of technologies. These are particularly important in the context of ATs because the data might be particularly sensitive.

In this project, four countries were selected, taking care to include old and new Member States, different geographical regions, country sizes, cultures, economic performance and regulatory contexts for ATs. Each of these countries has adopted the CRPD, including legislation to combat discrimination and promote the inclusion of people with disabilities in society, as well as further measures in more specific fields such as employment, housing, and healthcare. However, the CRPD and other anti-discrimination rules do not have uniform compliance and their effectiveness can be uneven, leading to substantial variations between countries. There are several reasons for this, including the cultural, social, economic, demographic, legal and other differences between Member States, the fact that they can interpret and implement EU regulations in different ways, and the fact that they retain full control over education and other key aspects of citizens' lives. These divergences are further intensified by various gaps and misalignments in the implementation and enforcement of laws once they are put into place.

There are also several features which vary substantially between different regulatory frameworks, leading to widely divergent experiences of people with the same disabilities in different Member States. For example, with regard the fundamental legal status of people with disabilities, in Sweden, people with disabilities possess full legal capacity with access to decision-making support where necessary, while in Portugal, on the other hand, people under guardianship may have limited rights to enter into legal commitments regardless of the presence of mental handicaps.

The authors of the study describe the policy frameworks in Germany and Sweden as more decentralised and flexible than those of Hungary and Portugal, which means they are more capable of responding to the individual needs of their citizens. While the policy framework itself in Hungary and Portugal was described as 'well adapted', there are difficulties in assigning resources to improve the living conditions and social integration of people with disabilities. Different models of financing the provision of ATs for people with disabilities are observed across the four countries. In Portugal, there is relatively little public funding for ATs, so the costs are covered by people with disabilities and their families. In Hungary, ATs

are most often provided by NGOs and the budgets for them are limited. In Germany and Sweden, financial resources are dedicated to ATs but the level of support varies depending upon the individual needs of the person.

4. Current and emerging assistive technologies

The following sections describe some of the key ATs for blindness, deafness and ASDs, in each case reviewing the range of ATs that are currently available before moving on to describe emerging technologies and the ATs that may become available in the future. The chapter then concludes with a sketch of broad trends in ATs and some overall reflections.

Read more about trends in ATs in Part II: Current and emerging technologies.

4.1. Current and future ATs for the blind and visually impaired

There are several types of AT currently available to assist the blind and visually impaired. Many are designed to convey information via touch or sound that would more often be received visually. Some of the best-known ATs for the blind and visually impaired are 'haptic aids', based upon the sensation of touch. These include traditional low-tech devices such as white canes and Braille texts, as well as embossed or tactile maps and textured surfaces to support navigation. There are also more high-tech equivalents of these haptic aids, such as advanced Braille applications, smart/advanced canes and haptic computer devices. Another way of categorising ATs for the blind and deaf depends upon the level of independence achieved by the individual. Primary aids provide sufficient information for blind or visually impaired travellers to achieve tasks safely and independently. Taking the example of travel and navigation, these include traditional canes and modern obstacle and object location detectors, combined with an appropriate audio or haptic alerting system. Secondary aids, on the other hand, are not sufficient alone and must be used in along with a primary aid or a helper, which could include wearable orientation devices which are used as a supplement or alternative to standard GPS supported navigation devices. Embedded technologies, such as tactile signage systems, make the environment easier to navigate. Some systems may blend these modalities in different ways. Several ATs are also available to support the blind and visually impaired in accessing information and communication technologies such as televisions, computers, the internet, telephones and smartphones. These may be designed for specific purposes – such as education, employment or recreation – and can adapt to a user's needs by, for example, magnifying or intensifying a display, or translating visual information into other sensory modalities such as sound and touch. There are also several technologies available to assist with the independent performance of daily tasks such as personal care, timekeeping, food preparation and consumption, environmental control and household appliances, and money, finance and shopping.

ATs for the blind and visually impaired that are not commercially available but under development include so called 'bionic eyes', which are essentially devices that are designed to replace functioning in the optic system, e.g. by converting light to electrical impulses. Augmented reality spectacles may help users by magnifying images, filtering colours and providing object and facial recognition assistance by audio. The study also identified some key trends in the development of future ATs for the blind and visually impaired which are enabled by wider mainstream technology developments. For example, user-led 'democratised' design and production is made possible by the emergence of accessible 3D printers and development tools, improved wearability and portability is driven by miniaturisation and efficiency gains for power sources and more innovative displays and interface devices making use of improved touch screens, gesture recognition, brain interfaces and haptic feedback systems can also benefit ATs for the blind and visually impaired.

4.2. Current and future ATs for the deaf and hearing impaired

ATs currently available for the deaf and hearing impaired can be categorised into three main categories: hearing, alerting and communicating. ATs can augment people's hearing ability by adapting the volume and other qualities of sound in a way that is useful for the individual. These technologies include hearing aids, assistive listening devices and personal sound amplification products increase sound levels within targeted frequencies. Cochlear implants also fit into this category, as surgically-implanted sensors that convert sound inputs into electrical signals that are directed to the auditory nerve. These are often given to deaf children to support them in developing speaking and listening skills and, ultimately, to facilitate social integration. However, the technology has raised some ethical debate, including criticism that it makes like easier for the hearing, rather than the deaf. Other ATs for the deaf and hearing impaired are designed to alert the user about specific events that would usually be announced audibly, via light, vibration or a combination of the two. The third category is communication technologies, which deploy a range of keyboards, touchscreens and video technologies as well as tools to translate between speech, text and sign to facilitate communication. These can be used for face-to-face or telecommunication interactions.

Advanced versions of many of these technologies are under development, including advanced auditory brainstem implants that can bypass the inner ear and acoustic nerve to stimulate brainstem neurons directly. These are intended for those that cannot receive a cochlear implant. There are also many gradual improvements and combinations of existing technologies, such as the integration of sign language into translation tools, that are improving rapidly and might be effectively combined with new interfaces such as augmented reality glasses.

4.3. Current and future assistive technologies for autism spectrum disorders

Assistive technologies for people with ASDs differ substantially from the ATs for deaf and blind people presented in the previous sections. First of all, since the causes and effects of ASDs are not as well-understood as those of hearing and visual impairments, ATs for ASDs are much less mature. Furthermore, individuals with ASDs have very different needs from the deaf and blind, who can benefit from ATs that augment their hearing or seeing ability, or that can convert communications, interactions and experiences to alternative sensory modalities. The ATs that are available for people with ASDs are focused principally on skills for communication, social interaction and independent living. ATs for communication are designed to help people with ASD to interact with others, and may use gestures, signs and body language (unaided systems) or objects such as cards or screens (aided systems). People with ASDs can also make use of dedicated software and specialist 'video games' to rehearse social interactions such as making eye contact and recognising people, expressions and emotions. Other ATs have also been developed to help people with ASDs to live more independent lives. These can include instructional software and games to rehearse daily activities.

There are several types of AT under development for ASDs. These include so called 'social robots' that interact with children and simulate human interactions and emotional states to help develop social skills such as empathy and non-verbal communication. Although children with ASDs often show interest in robots and computers, the clinical utility of ATs based upon these technologies has not been fully established. Another avenue of exploration is to use smart glasses or other devices to provide the user with information about their social context. In these cases, it is important to fine-tune and, generally, decrease the amount and intensity of sensory, cognitive and emotional stimuli. ATs might also be used to understand more about the sensory information disorders that are associated with ASDs.

4.4. Overall reflections on assistive technologies

Taking all three types of AT together, there are more devices for blind and visually impaired people than for the other groups, and these technologies can perform a wider set of functions. This may result from demographics, since many people experience visual impairments of some kind, more resources are

available for the development of associated ATs. It may also be a result of the greater familiarity with visual impairment and ATs such as glasses and canes, which have been around for a very long time.

Specific technologies can be characterised in various ways, such as high- versus low-tech, specialist versus mainstream, enhancement versus accessibility, augmentation versus automation and integration versus inclusion. While the huge range of ATs in use vary significantly in how they are characterised according to these scales, some general tendencies and trends can be identified.

ATs are rarely very low-tech (e.g. mechanical, familiar, cheap) or very high-tech (e.g. advanced, complex, expensive), with most lying somewhere between the two. While some ATs are specialist devices intended for a rather specific group of users, there is increasing blending of ATs and mainstream technologies such as text to speech converters that can assist people with and without disabilities. This trend may be partly to do with the rise in universal design principles that call for simple, flexible products that can cater for a wide range of people. As mainstream technologies increasingly embrace multiple sensory modalities at the same time – with interfaces integrating touch, sound and vision – there may develop greater flexibility to decide the format in which information is received according to whims, preferences and abilities to communicate. This would further blur the boundary between assistive and mainstream technologies. Considering this blurring in the context of some emerging and possible future ATs, it may become difficult to distinguish ATs from prosthetics that could be used for augmentation purposes, regardless of disability. This could pose a myriad of legal, ethical and social questions.

The study found that current and emerging ATs tend to target the automation of tasks as a substitute for human labour, rather than the augmentation of human labour by blending technology in a way that enhances human control and efficiency. This means that ATs may end up taking over more tasks that are currently performed by human caregivers. Broadly, ATs are following a trend towards more inclusivity, whereby greater social assimilation is sought in ways that protect and preserve individual diversity. This contrasts with integrative ATs, which seek to achieve social assimilation by reducing the differences between people. This trend follows a broader call for attitudinal change, so that disabilities are seen as biological variations like any others and, furthermore, are accepted as such. Several ATs aim to increase the autonomy of the user by accounting for an impairment or making contextual changes. This trend is positioned in response to the social value placed upon people living independent lives. However, focusing on autonomy and independence without considering the individual's circumstances could risk resulting in isolation or social exclusion.

5. Perspectives on ATs

For the next part of the study, a large-scale survey of actual and potential users of ATs was conducted, as well as in-depth interviews with experts on the technical and regulatory aspects of ATs, and a workshop held at the European Parliament to explore challenges and opportunities together. The focus remained on hearing impairments, visual impairments and ASDs, and the studies were designed to explore the needs, perspectives and opportunities of ATs for independent living, education and employment.

5.1. Survey of current and potential users

The survey was designed in dialogue with disability associations and pilot surveys were undertaken to maximise accessibility. A total of 149 associations were contacted to support the distribution and promotion of the survey, in which 373 individuals took part. However, these participants were not evenly spread in terms of disability, location or age. Approximately 60 % of respondents were blind and visually impaired, with the remainder split evenly between respondents with ASDs and deafness or hearing impairments. Approximately 60 % of all respondents came from six countries (Italy, Ireland, Estonia, Denmark, Austria and the UK), and around 60 % were aged between 34 and 65. The reasons for these disparities could

Read more about the method and findings of the survey in Part III: Perspectives, needs and opportunities.

include language barriers, as the survey was conducted in English, or uneven effectiveness in the promotional activities. While this limits the representativeness of the survey, the insights remain useful and feedback on the questionnaire was, overall, very positive.

The survey confirmed that many barriers to full social inclusion remain. While these varied depending on the type of impairment, all three disability groups reported physical, infrastructural, communicative, informational, social and attitudinal barriers. Respondents from the three groups shared a dissatisfaction with current regulations, which they felt required improvement in order to facilitate their access to employment, education, finances and everyday support. With regard to ATs, the surveys show that most people with disabilities had an open and optimistic attitude to new and emerging technologies. Approximately 90 % of deaf and blind respondents already used ATs, compared with about 50 % of respondents with ASDs, although these figures may be disproportionately high given that the survey was conducted online. It should also be noted that approximately 70 % of respondents considered non-technical assistance to be important, and over 90 % identified accessible environments and barrier-free infrastructures, and an open-minded and prejudice-free society, as being important to them. A majority of respondents agreed that ATs should be financed and provided by the state. The survey also revealed the respondents' core expectations for ATs as being ease of use, flexibility, adaptability and affordability.

Differences between the three groups were found when it came to understanding the reasons for use and non-use of ATs. For many, ATs are considered a necessity for several key tasks such as reading, writing, mobility and accessing information. However, they were more important in the lives of people with hearing and visual impairments than for respondents with ASDs. Blind and visually impaired respondents reported the highest level of dependence on ATs, followed by the deaf and hard of hearing respondents and those with ASDs. The reasons for not using ATs also varied between the three groups with the blind and visually impaired respondents citing support from other people, deaf and hard of hearing respondents reporting that ATs did not meet their needs, and respondents with ASD highlighting a lack of information about the ATs available. All three groups also highlighted the prohibitive cost of ATs as a reason for non-use. Participants had the opportunity to identify potential future technologies that would be useful in their lives. Blind and visually impaired respondents highlighted autonomous vehicles, deaf and hearing impaired respondents highlighted sign-to-speech translators and devices to help them hear in challenging listening environments, and respondents with ASDs highlighted innovations in therapy and training, emotion recognition devices and social robots.

5.2. Expert interviews and workshop

Read more about the interviews and workshop in Part III: Perspectives, needs and opportunities.

The study also included a set of 12 interviews, and a workshop with a wide range of experts. The interviews focused on the experts' opinions on the perspectives of current and potential users of ATs and complementary public sector measures towards a more inclusive society. The workshop took place in the European Parliament in January 2016 and was designed to explore several aspects of the future of ATs, notably, technological, regulatory, social, economic, ethical, environmental and demographic aspects. The 25 participants included members of the project team, staff from the European institutions and guest experts.

The experts broadly agreed that there was a need for improvement when it came to disabled people's inclusion in society, education and employment, and to the accessibility of all kinds of infrastructure, from transport to knowledge. With some critical reservations, the experts shared the survey respondents' broad openness to technology and enthusiasm for its potential role in responding to some of the challenges to inclusion faced by people with disabilities.

The interviews and workshop also revealed two broad and conflicting approaches to the basic definition of ATs. One approach is to define ATs as those devices that are designed specifically to assist people with disabilities, while another approach is broader, including any technology that has a wider market

including people who use them to assist in overcoming barriers related to disabilities. The distinction between mainstream and assistive technologies is increasingly difficult to identify with several technologies, including smartphones, meeting mainstream needs while also giving specific assistance to people with disabilities.

Some experts highlighted the cost of ATs as a significant barrier to access, which can cause further social inequalities, emphasising that insufficient attention was paid to post-purchase costs such as training and servicing. Demographic differences were also noted, with younger people more accepting of ATs, with older people expressing more unease and reluctance to introduce ATs into their daily lives. ATs were also associated with some social stigma, particularly those such as hearing aids that are both visible and specifically made for people with disabilities, without a mainstream market. Here, experts mentioned the blending of assistive and mainstream technologies as a means of redefining ATs as 'normal' products and overcoming stigma while also achieving economies of scale that could drive prices down. However, some devices simply have little potential to develop mainstream markets and, in any case, social stigmas may be better addressed by social change, rather than by tweaking the design and use of technologies.

Some experts called for the development of ATs specifically to support people with ASDs in communication and social interactions, which are particularly important for accessing health systems and public services. ATs can form a crucial means for people with disabilities to access educational services, but it is important that other professionals are educated to understand and meet the needs of people with disabilities, for example in their access to health and other public services as well as internet and other computer interfaces. Depending upon the disability, ATs can help people to access employment by preparing them for difficult situations or providing tools that enable them to interact with colleagues and perform a wider range of tasks. However, the technologies that focus upon people with disabilities can only go so far, and many non-technological barriers to employment remain, chiefly attitudinal and informational. The CRPD includes a requirement of 'reasonable accommodation in the workplace', but many would-be employees and employers are unaware of the opportunities and needs of disabled people at work.

Looking to the future of ATs, the experts highlighted several technological advancements that could help support the inclusion of more people in society, education and employment. These include software such as facial recognition, particularly for people with visual impairments and ASD, as well as advanced hardware such as brain-computer interfaces. However, above and beyond the use of advanced materials and techniques, they stressed the importance of developing and making ATs available. In particular, they identified the need to roll out universal design for all technologies, to include people with disabilities from the earliest stages of the development process, to improve the connections between technologies and services, to ensure robust quality assessment, and to facilitate access and uptake of existing technologies.

6. Future trends

A number of key future trends for assistive technologies were identified and explored in the course of the study and are presented below.

6.1. Technological trends

Among all the ATs that are under development, the focus is often placed upon high-tech devices such as brain-machine interfaces, bionic eyes and augmented reality. These often present technological fixes to what is seen as the medical problem of disability, rather than presenting holistic solutions to the largely social problem of inclusivity. While there is widespread enthusiasm for the role of technology in achieving greater inclusion of people with disabilities, it must be appropriately embedded in the social context. This points to a stronger role for universal design as well as more participatory technological development, where a wide range of users are included from the earliest stages in the development of all new technologies, whether they are mainstream or assistive. It was also highlighted that existing ATs –

numbering over 60 000 in Europe – are not always used to their full potential, and that consideration should be given to whether more can be done with these technologies, in particular with regard their integration into social services, health, education and employment. In this sense, the development and diffusion of ATs does not depend upon new high-tech solutions, but on social and political action towards inclusion through various means, including technology as well as education, equality, attitudinal change and other initiatives.

6.2. Regulatory trends

The ways in which regulations such as the CRPD and EAA are implemented and enforced will have a substantial impact on the development of ATs as well as their effectiveness in enabling greater social inclusion of people with disabilities. There are several ways of responding to requirements such as reasonable accommodation. While structural changes and organisational reforms may be more costly, they are also expensive. Financial constraints may favour cheaper technological fixes without efforts to target deeper social change, or the social embedding of technology. Another key regulatory feature is whether ATs are classed as medical devices, which would mean they would fall under the strict Medical Device Directive, rather than being regulated in the same way as other consumer goods. One suggestion in response to this situation is to develop a more nuanced classification system, going beyond the binary classification of devices as either medical or non-medical to allow the appropriate classification and regulation of mainstream devices that are 'disability inclusive' as well as ATs that are also ready for mainstream markets. The demographic trend of an ageing population in Europe is expected to lead to higher prevalence of hearing and visual impairments, which could in turn lead, via the polls, to a more disability-friendly regulatory environment that focuses more on ATs than on medical diagnosis and cures for social adaptation and inclusion.

6.3. Social trends

Social trends such as more individualistic lifestyles, decreased solidarity and disrupted support networks all point towards greater priority being given to people's autonomy. Some current ATs already reflect these trends by enabling their user to perform tasks alone that would usually require human assistance. If it is assumed that these trends will continue in the coming years, they could lead to problems such as social deskilling and emotional isolation. Of course, many ATs that are focused upon communication enable people with disabilities to communicate with those around them, and all over the world. These ATs combined with social efforts to foster human interactions and relationships will be important in ensuring that more autonomy does not mean more isolation.

6.4. Ethical trends

Several ethical issues were raised in the course of the study, often framed as open questions such as whether or not there should be limits to the integration of technologies into human bodies. Many people evaluate technologies differently if they go beyond assisting to enhancing the user, whether they have disabilities or not. This distinction between assistance and enhancement is becoming more and more blurred, especially as it rests upon a notion of bodily 'normality' that is increasingly disputed. If the use of technological assistance (and, perhaps, enhancement) becomes widespread, those who are unable or unwilling to accept it may suffer discrimination or face barriers, e.g. in finding employment. Where technologies affect the intellectual and sensory functioning of the user, it is reasonable to ask to what extent the user is experiencing their own reality or some virtual or augmented version of it. In cases where a technology is fully embedded in the individual, it could reasonably be considered part of their body and, if so, what implications could that have for the intellectual property rights of the owner. ATs might also introduce new opportunities for coercion or exploitation, for example in offsetting the cost of new technologies by monetising the valuable personal data that they could gather, or in presenting opportunities for criminal hacking and extortion. Many of these questions have no absolute answer, implying that reflection and debate should be encouraged amongst a wide range of experts and publics.

6.5. Economic trends

Long-term economic trends – such as the budget allocated to the health services, credit available to innovators and levels of household income – were considered to have an important impact on the development of ATs. In particular, those ATs that are formally categorised as medical devices entail substantially higher investment costs and take longer to reach the market, often excluding smaller companies with insufficient economic power, skills and experience. The experts also explored different approaches to financing the development, distribution and further lifecycle costs of ATs. This includes several methods of provision by the state, private insurance, households and charities, highlighting the close connection between economic, regulatory and political trends. The full cost of ATs, including ongoing training and servicing, is often much higher than the cost of the device itself. On the other hand, the full benefit of ATs is not always accounted for. For example, there are economic benefits of a larger proportion of the population being socially integrated, mobile and in employment. Also, several ATs such as text-to-speech technologies and voice control features have knock-on value as they are adopted for use in mass market products, such as in smartphones.

6.6. Demographic trends

Demographic aspects are crucial to understanding the future of disability in society as well as ATs. The ageing population is often discussed in terms of higher pension costs and the need for people to stay in the workforce for longer. However, as the population ages, so too will the proportion of people with age-related disabilities such as visual, hearing and mobility impairments. This group differs from others that have disabilities from a younger age in that they are more likely to have a combination of impairments (e.g. both hearing and visual impairments) and face more barriers in adapting to their situation and in embracing ATs. The development and effective roll-out of ATs that enable people with disabilities to remain in the workforce may be a crucial factor in Europe's success in meeting the challenges of an ageing population. There may be some opportunities in terms of reducing stigma and achieving economies of scale. However, there remain many differences between lifelong disabilities and those related to ageing, and a 'one-size fits all' approach is not considered appropriate.

6.7. Environmental trends

The study found that environmental aspects of ATs are highlighted less often than other aspects, perhaps because there is little difference between the environmental footprint of ATs and that of other technologies, which focus largely upon energy and materials. The energy efficiency and storage capacity of ATs is also important for their usability. Attention should also be paid to the reusability, recyclability and disposability of all components, especially those that make use of rare earth elements. While some higher-tech ATs may have a high energy and material cost, many use little power or none at all, relying instead upon human labour. Such technologies are likely to have a much lower environmental burden.

6.8. Future scenarios

Read more about the scenarios in the annex to Part III: Perspectives, needs and opportunities.

The findings of the research were used to construct four scenarios for the future of AT. Each scenario describes a distinct possibility for the future that is ultimately speculative, but based firmly upon the findings of the reviews, surveys and interviews conducted as part of the study. They are not presented as predictions but, rather, as collections of consistent and plausible future developments. As such, each scenario is not presented as an option that can be chosen, but rather as part of a suite of ideas and insights which can be used to reflect upon and discuss the whole range of opportunities and challenges presented by ATs, and to consider what kind of action could be taken to foster their development in a desirable way.

The scenarios all take place in 2050. While some features remain constant across all four, such as an ageing population, each scenario describes a very different socio-technical reality. The key differences between

these futures is the extent to which society is inclusive or prejudiced, the level of technological advancement, the extent to which technologies are embedded in social structures and practices, the economic situation, and the public versus private approach to the provision and financing of ATs. Brief sketches of the four scenarios are presented below.

Mid-tech solutions in an inclusive society European societies no longer marginalise people with disabilities. They have matured into fully inclusive societies that accept differences and minorities of all kinds. The distinction between disabled and non-disabled people has largely disappeared, with people considered on a spectrum of ability which can change during their lives. Low- and mid-tech ATs are widely used to enable inclusion.	**Technological fixes in a prejudiced society** European societies have become increasingly inward-focused and intolerant to difference. Able-bodied people are seen as naturally and inevitably superior to people with disabilities. While medical advances and technological fixes have greatly reduced the prevalence of disability, the development and access to non-curative ATs is limited, and people with disabilities are subject to discrimination.
High-tech reliance in an individualistic society Europe has benefited economically from technological advances, yet the ageing of the population has led to a higher prevalence of disabilities. Given the trust in technology, a medical model has been re-established whereby disabilities and differences are 'fixed' by advanced technologies. Participation in society, education and employment depends on the individual's ability to integrate, rather than society's capacity for inclusion.	**Privileged use of technology in a divided society** Social and economic divisions permeate European society. Those that can afford private healthcare and ATs opt-out of the social welfare system. While state healthcare is still offered, many are unable to access it and, in any case, many ATs are only available on the private market. This means that access to ATs depends upon the individual's economic position and many people with disabilities have no such access.

6.9. Legal analysis

Read the legal analysis in Part IV: Legal and socio-ethical perspectives.

The final part of the project is the presentation of social, ethical and legal reflections on the role of current and future initiatives of the European Parliament in the context of trends in the field of AT. The analysis identifies various legal challenges that ATs raise in the context of EU law including the coordination of the various layers of competence, the lack of a commonly accepted definition, the variety of risks posed by ATs to human rights, privacy, dignity, access to employment, freedom and social inclusion of people with disabilities. It also identifies wider concerns including the changing concept of what a 'healthy human body' is, medical classifications, social stigma and financing the development and provision of ATs. In response, several options for responsive policy action are suggested. These include ensuring accessibility as a human right, privacy by design, improving the informed consent process, a user-centred model of technology design, autonomy of choice to use ATs, maintaining the availability of human care, developing appropriate ethics oversight structures, introducing a new classification system for ATs and ensuring the safety of their use.

7. Conclusions

7.1. Current and future ATs could have a positive impact

Given the social technical and regulatory trends identified, it is clear that ATs are to play an increasingly important role in the lives of people with disabilities, supporting their further inclusion in society, education and employment. However, an active approach should be taken, including measures to ensure the effective distribution and use of current ATs, and to foster future ATs to maximise their value. Such steps could include encouraging the involvement of people with disabilities in the development of future ATs from the earliest stages. It may also be valuable to promote the development of new occupational profiles dedicated to ATs. These could help people – with and without disabilities – to make the best use of existing ATs in their particular situation and provide useful inputs for developers of new ATs.

7.2. One size does not fit all

By focusing upon ATs for three specific disabilities, it was possible to identify and explore some key issues for the future of ATs in society in some depth. However, it is important to recognise that everyone has a different set of circumstances in terms of ability and disability. Many people have multiple disabilities which affect their care needs. Further differences can be found in the individual's social and economic resources as well as in their personal needs, desires and preferences. Others are subjected to multiple forms of discrimination, as highlighted in a recent report on the problems facing women with disabilities in the workplace. This wide range of individual circumstances raises several problems for one-size-fits-all approaches to the challenges of inclusion. One response to this problem could be to train a new generation of assistive technology professionals to support individuals in finding the right solutions for their situations.

7.3. Technology alone is not enough

While ATs clearly offer significant support for some aspects of some people's lives, it is also important to consider social and regulatory action for the inclusion of people with disabilities in society, education and employment. In the workplace, for example, the study identified several ATs that could support people with disabilities to secure employment and pursue their careers, but these may need to be accompanied by social change to counteract stigma, and also organisational changes, such as the provision of flexitime and teleworking arrangements.

7.4. Action to target people without disabilities

It is important that action to respond to the challenge of inclusivity does not target people with disabilities only. For example, the problems of discrimination and stigma require broad attitudinal and organisational change that permeates society. Wider actions are also required in the more specific area of ATs. For example, many people will increasingly encounter ATs in their professional and personal lives, for example as communicative tools. Understanding how to engage with others through these means will be particularly important for health professionals and other public services, as well as for the designers of digital services and other infrastructures. Again, assistive technology professionals could play an important role in these activities.

7.5. How to start building a more inclusive society today

The study described a range of future technical and regulatory developments that could offer substantial support for the inclusion of people with disabilities in society, education and jobs. However, it also highlighted the range of technologies and regulations that are already available but are not used to their full effect. While waiting for future ATs, the focus could be on the implementation of current legal frameworks such as the CRPD, exploring how current technologies can be used more effectively and taking steps to overcome social discrimination and stigma. The future may be promising, but steps can already be taken now to achieve a more inclusive society today.

Assistive technologies (ATs) are designed to improve the functional capabilities of people with disabilities. Some are relatively low-tech and very familiar, such as such as reading glasses, crutches and hearing aids. Others are more advanced, using cutting-edge science and technology, with future ATs under development that could have a huge impact on all our lives. This briefing provides an overview of a scientific foresight study of ATs for three specific types of disability: blindness and visual impairment, deafness and hearing impairment, and autism spectrum disorders.

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